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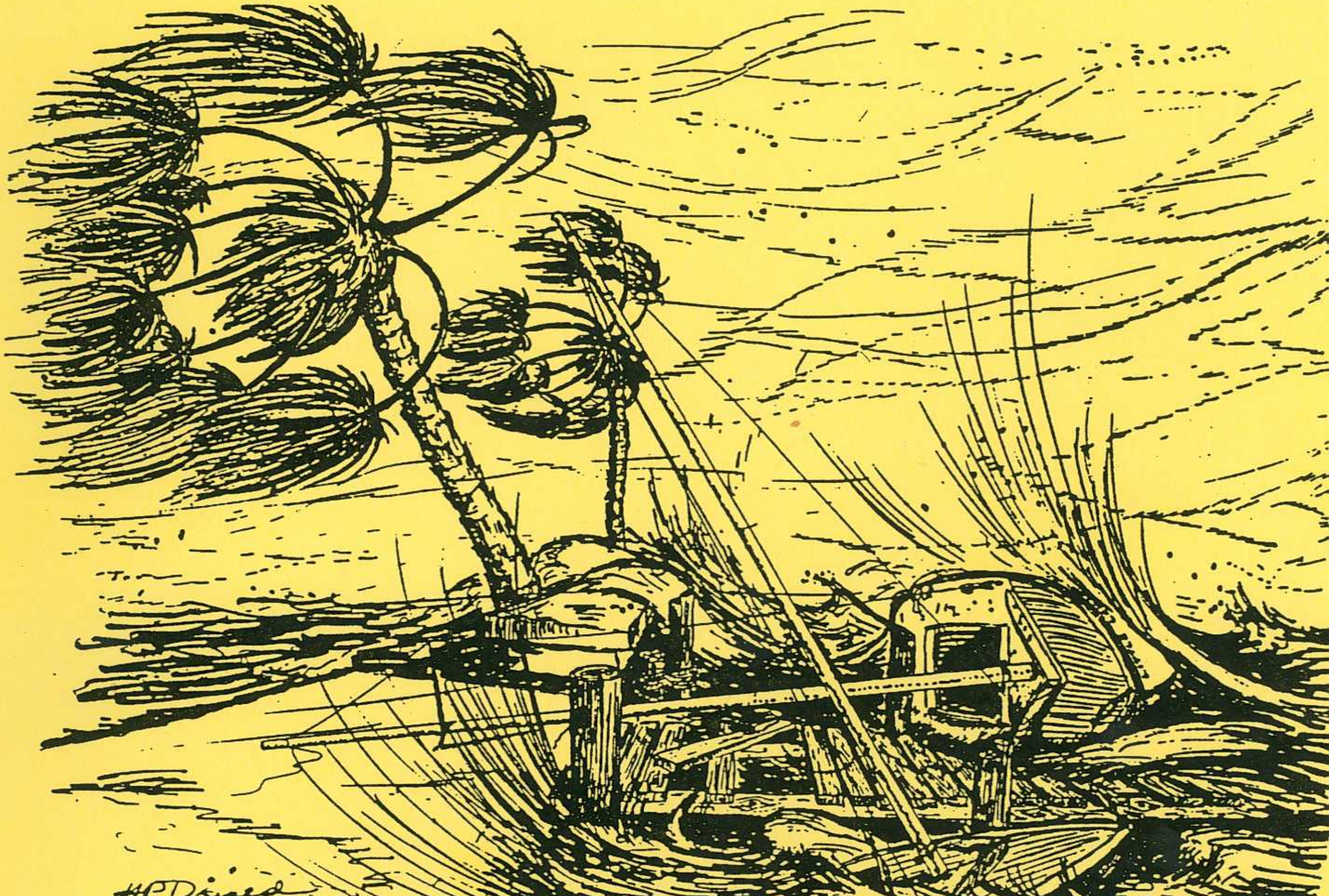
US Army Corps
of Engineers

TECHNICAL GUIDELINES

for Hurricane Evacuation Studies



Revised September 1995

TECHNICAL GUIDELINES FOR HURRICANE EVACUATION STUDIES

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FOREWORD

In March 1994 the National Hurricane Program Task Force was established to assist the Federal Emergency Management Agency (FEMA) with planning an enhanced Hurricane Program. Several work groups were formed within the Task Force to address proposed components of that program. Since, for several years, the preexisting Interagency Coordinating Committee on Hurricanes (ICCOH) had managed hazards analysis, population preparedness, and post-storm analysis issues related to the Population Preparedness Project (Hurricane Evacuation Study) phase of FEMA's Hurricane Program, that committee was asked to function as a Task Force work group for those topics. To support the work of the ICCOH, Headquarters, U.S. Army Corps of Engineers (USACE) subsequently organized the Hurricane Evacuation Studies Technical Guidelines Working Group.

USACE Study Managers, FEMA Regional Hurricane Program Managers, the National Weather Service, the American Red Cross, and state and local governments were represented on the Working Group and its task forces. The Working Group was charged with examination of a variety of issues related to the execution and use of Hurricane Evacuation Studies (HES). Members were instructed to provide, where appropriate, recommendations for innovations or improvements.

These revised guidelines, an update of the November 1984 guidelines produced by the Jacksonville District, USACE, resulted largely from the HES Technical Guidelines Working Group's efforts. This document was prepared by the Wilmington District's Flood Plain Management Services Branch on behalf of Headquarters USACE and in support of the ICCOH and the National Hurricane Program Task Force. It has been fully coordinated with FEMA. The methodologies described herein are based on previous HES procedures and recommendations to the ICCOH by the HES Technical Guidelines Working Group. They are intended as a flexible framework within which USACE Study Managers can effectively develop important basic information and translate it to local officials. The study process includes methods of applying the information in formulating preparedness plans and of educating the public to hurricane hazards and evacuation procedures. Broad use of these guidelines should provide uniformity of terminology and content to a complex study process. While these guidelines were prepared to assist USACE Study Managers, they may be useful to other agencies managing HES or components of studies.

INTRODUCTION

Coastal areas of the United States are experiencing rapid change, with tremendous development and population increases occurring over the past 20 to 25 years. According to the U.S. Census Bureau, over 75 million people live in coastal counties along the Atlantic and Gulf coasts. Because of the influx of new residents and the infrequency of hurricane strikes at most locations, a large percentage of the coastal residents from Texas to Maine have never experienced a direct hit. However, hurricanes are "low frequency-high consequence" events, and damage caused by recent storms has shown that even locations far inland are not safe from intense storms. In some areas, hurricane hazards are exacerbated by evacuation times that exceed the National Hurricane Center's goal of providing a 24-hour warning.

Currently, officials at all levels of government are striving to greatly improve the ability of coastal populations to respond to hurricane threats. In particular, emergency management officials are faced with the difficult task of developing hurricane evacuation plans that can more reasonably ensure safe and effective evacuations of the threatened population. Development of the critical data needed as a basis for these plans often requires comprehensive and specialized analyses. The fiscal and staffing limitations of most state and local emergency management agencies preclude the development of these data. Consequently, the U.S. Army Corps of Engineers, the Federal Emergency Management Agency, and the National Oceanic and Atmospheric Administration have joined state and local governments to produce the needed technical information by conducting hurricane evacuation studies.

TECHNICAL GUIDELINES
FOR
HURRICANE EVACUATION STUDIES

AUTHORITY AND FUNDING

a. U.S. Army Corps of Engineers (USACE).

Allocation of USACE resources for planning activities related to hurricane preparedness is authorized under the Flood Plain Management Services (FPMS) Program, established by Section 206 of the 1960 Flood Control Act, as amended. In order for the USACE to manage a Hurricane Evacuation Study (HES), a written request must be received from the chief emergency management officer or higher of a state.

b. Federal Emergency Management Agency (FEMA).

Through Executive Orders 12148 and 12673, FEMA is assigned primary Federal responsibility for carrying out the functions of the Robert T. Stafford Disaster Relief and Emergency Assistance Act of 1988 (Public Law 93-288, as amended). Under this authority, FEMA administers the Hurricane Program. FEMA authorization for HES funding requires an application from the governor or the chief emergency management officer of a state.

c. National Oceanic and Atmospheric Administration (NOAA).

(1) NOAA's National Weather Service (NWS) contributes to the HES program through the Techniques Development Laboratory (TDL) and the National Hurricane Center (NHC). In addition, the Atlantic Oceanic and Meteorological Laboratory (AOML) provides staff support to the NHC for the studies. Using NWS funds, the TDL develops the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) numerical models that are the basis for each study. Partly with outside funding, the NHC makes the hundreds of SLOSH computer runs that are necessary to define the hurricane threat for each evacuation study area. NWS officials, especially Meteorologists in Charge (MIC) and Warning Coordination Meteorologists (WCM) of local NWS offices, have made substantial contributions to evacuation studies by

actively participating in public meetings and by serving as consultants to the study managers.

(2) Through its Coastal Zone Management Program (CZMP), NOAA's Office of Ocean and Coastal Resources Management (OCRM) is authorized to provide funds to appropriate state agencies for hurricane preparedness. Under this program, application may be made by the state to OCRM for hurricane evacuation study funding.

d. Other Study Participants.

Other Federal, state, and local agencies should be encouraged to actively participate in Hurricane Evacuation Studies to the greatest extent possible, including sharing in the study costs by providing cash contributions and/or contributory services. Agencies that should be considered include the following: state emergency preparedness and coastal management organizations; state departments of transportation; military installations; and the American Red Cross. A state may seek funding support from local governments and organizations (e.g., regional planning agencies, development commissions, etc.) and the private sector. States also may use available Federal program funds.

e. Accepting Non-Federal Funding.

ER 1140-1-211, Support for Others: Reimbursable Work, provides guidance on the acceptance and funding of work for non-DOD Federal agencies, States, Commonwealths, Territories, and local governments of the United States. OMB Circular A-97 contains rules and regulations permitting Federal agencies to provide specialized or technical services to state and local units of government under Title III of the Intergovernmental Cooperation Act of 1968. In order for the USACE to accept non-Federal funds from state or local governmental agencies, those agencies must provide a written request for services and certify that such services cannot be procured reasonably and expeditiously through ordinary business channels. Exhibit 1 is a sample letter of request. Other significant issues involving use of non-Federal funds include:

(1) Approval to accept and perform reimbursable work must be obtained from the Division Commander or heads of field operating activities. In some cases, the Division Commander may have delegated authority to accept some types of reimbursable work to District Commanders. Opportunities exceeding their authority

may be approved by Headquarters, U.S. Army Corps of Engineers (HQUSACE), depending on the scope of the work and other criteria outlined in paragraph 7 of ER 1140-1-211. Samples of a district request and division approval are shown as Exhibits 2 and 3. Note that the referenced ER's have been revised.

(2) For non-Federal reimbursable work, funds must be on deposit with the Treasury in advance of USACE Commands incurring obligations for the work, in accordance with AR 37-1, Army Accounting and Fund Control, unless there is specific statutory authority to the contrary. Some state and local agencies have restrictions on providing funds in advance, but may be able to establish escrow accounts.

(3) Work to be performed should be defined in a Memorandum of Agreement (MOA) between USACE and the contributor. A sample MOA is shown as Exhibit 4.

f. Accounting Procedures.

Financing and accounting for support for others shall be in accordance with ER 37-2-10 and other appropriate staffing and financial regulations listed in paragraph 3 of ER 1140-1-211. FEMA funding for HES activities is arranged by HQUSACE through an Interagency Agreement (IAA) with FEMA National Headquarters. HQUSACE will furnish guidance concerning current accounting procedures with each project order. A specific statement of work for each project funded under this IAA will be developed between the appropriate FEMA region and USACE district.

OBJECTIVES

The overall objective of an HES is to provide emergency management officials with state-of-the-art information on the major factors affecting hurricane evacuation planning and decision-making, and the skills and training aids necessary to educate the public.

An HES should be comprehensive in scope and multi-regional in perspective; analyses should cross state boundaries where necessary. This approach will ensure that the need for interaction among the various evacuating jurisdictions during a hurricane threat will be recognized. Where traffic and/or sheltering concerns will affect locations far removed from the evacuation area, state-wide studies should be considered. The technical data produced in a hurricane evacuation study should be presented in a documented report suitable for use by public officials in preparing or updating evacuation plans. The data should also aid in developing operational procedures and decision guides for future hurricane threats.

The methodology of an HES should encourage cooperation between local emergency management officials, their state counterparts, local NWS officials, the NHC, the American Red Cross, the local news media, and other agencies and organizations involved in hurricane preparedness and evacuation. Close coordination between these agencies will facilitate more effective responses at the local level to hurricane emergencies. The end result should be a prepared government and an informed public.

MANAGEMENT

Flood Plain Management Services units at USACE district offices normally conduct HES and assign one person as the USACE Study Manager. Selection of a Study Manager is one of the most important issues to be decided at the outset of an evacuation study. The manager should be energetic, open-minded, and experienced in project coordination involving extensive direct and active participation of Federal, state and local agencies. That person should be given the lead role as spokesperson and the responsibility for the successful completion of the study. Since it may fall to the Study Manager to explain to those impacted by the study how they fit into the hurricane preparedness process, prior knowledge of hurricane evacuation planning or disaster preparedness activities is very useful. From the beginning, presentations explaining the study, how it will be conducted, what the products will be, and how they can be used will put the Study Manager at the center of the communication process. Throughout the study, the dissemination of information generates more questions and requests for information. Study Managers are often looked to for "expert" advice in all aspects of preparedness planning and evacuation, and should be willing to share information and educate others.

Successful management of an HES requires a firm commitment by the USACE district to provide significant manpower, contract and administrative support, and other resources over at least a three year period. One of the Study Manager's first tasks is to furnish the District Commander an accurate estimate of the total resources that must be committed in order to successfully complete the study. If a firm commitment of these resources cannot be made, the district should decline the study.

In order to become familiar with the common terminology and techniques used in conducting hurricane evacuation studies, the Study Manager and others closely involved with the study should review copies of previously published studies, publications from the NHC, applicable hurricane evacuation plans, post-disaster reports from past hurricanes, and other pertinent hurricane evacuation related materials. To facilitate the study management technology transfer process, new managers should consult with other USACE personnel more experienced in this field. When possible, they should attend USACE/FEMA Hurricane Evacuation Study Program workshops, hurricane conferences, and other meetings concerning HES.

PLAN OF STUDY

a. Purpose.

The plan of study contains the basic descriptions of work and cost estimates that govern the overall conduct of the HES. It should be a useful tool for the Study Manager, allowing flexibility by describing the desired products of the major study tasks and, to the greatest extent practicable, leaving the means of producing those products to his/her discretion.

b. Development.

Before FEMA can authorize funds for an HES, a state must submit a written application to the appropriate FEMA Regional Director. A plan of study must be submitted by the state as part of its application, but it does not necessarily have to accompany the initial correspondence. If the USACE is designated the project management agency, the Study Manager should coordinate with the FEMA Program Manager and submit a draft plan for USACE Division approval. Since the hazards analysis is necessarily one of the first major analyses to be initiated, a realistic draft plan requires a commitment from the NHC on scheduling and costs for providing the SLOSH model simulations.

Prior to completion of the draft plan, one or more plan of study development meetings should be held with appropriate Federal, state, and local officials, and persons having technical expertise in fields related to the study. The purpose of these meetings is to discuss the proposed draft plan of study and to solicit comments and suggestions on the study content and techniques. Also, at these meetings, existing information and capabilities related to the study tasks should be identified. These plan of study development meetings should, at the least, include the following:

(1) A discussion of the importance of a close working relationship between Federal, state, and local agencies.

(2) An agreement on the scope and inland extent of the study area.

(3) A determination of needed and available data and sources of useful information.

(4) An inventory of the capabilities of the participating agencies, and an agreement on the roles and responsibilities of each of those agencies in the study effort. It should be clear that shelter selection and capacity determination is not a responsibility of the USACE.

(5) An assemblage of existing hurricane evacuation plans and a discussion of revisions or procedures for developing new plans.

(6) An inventory of existing evacuation times, evacuation routes, evacuation zones, and other pertinent existing evacuation data.

(7) Discussion of appropriate members of Disaster Preparedness Committees, including persons who will be directly involved during a hurricane evacuation.

Following the plan of study development meetings, comments should be incorporated into the draft plan, as appropriate, and the plan should be submitted to the USACE Division office for approval. In the 30 days following approval of the draft plan, the District should consult with the other sponsoring agencies and finalize the plan of study. Within 30 days after the final plan is completed, the district should provide published copies to the state requestor, who will then submit the document to FEMA to complete the HES application.

c. Contents.

The following points should be addressed in a typical plan of study. Descriptions should be concise and allow flexibility of execution.

(1) Purpose. Describe the purposes of the plan of study.

(2) Study Objective. Describe the objective of the HES.

(3) Study Description. Describe the study area, specific problems to be addressed, and study procedures.

(4) Scope of Work. The scope of work should contain a description of the proposed conduct of the study, including in-house effort, contracted services, in-kind services provided by all participating agencies, and coordination procedures. Also, a description of study methods outlining all technical evaluation and analysis procedures and reports should be included. Maintain flexibility to greatest extent practicable. A detailed scope of work may be included in the plan of study as an appendix.

(5) Summary of Deliverables. This summary is principally a narrative describing study products scheduled at predetermined milestones in the study. Availability of that data indicates the completion of specific study tasks.

(6) Study Schedule. A chart or diagram showing, by month, scheduled and actual work sequence, progress, and task completion dates for the entire study period.

(7) Cost Summary. An estimated cost for each major task or analysis, and an estimated total study cost.

The Study Schedule and the Cost Summary are working documents that should be periodically updated.

STUDY TASKS

a. General.

The HES process has evolved into what is presently a series of five major analyses that are interrelated and conducted in an efficient, logical order. The hazards, vulnerability, behavioral, shelter, and transportation analyses develop technical data concerning hurricane hazards, vulnerability of the population, public response to evacuation advisories, sheltering needs, and timing of evacuations for a range of hurricane threat situations. As the study progresses, some analyses produce data upon which subsequent analyses are based. **It is extremely important that this data, as it becomes available, is reviewed by the appropriate emergency management officials and Disaster Preparedness Committee members for their concurrence.** Also, during the progress of the study and prior to publication of the technical data report, products that will be useful in evacuation planning and decision-making can be developed and furnished to emergency management officials.

Generally, study coordination is the first task initiated and begins with the development of the plan of study and the organization of the Disaster Preparedness Committees. Since the hazards analysis and behavioral analysis are the only major analyses that are not based on the results of prior work, they are the first to be undertaken and can be conducted concurrently. The scope of the vulnerability analysis is dependent to a great extent upon the results of the hazards analysis, and the shelter analysis is partially based on data developed by the hazards analysis and the behavioral analysis. The transportation analysis utilizes information from all prior analyses. Decision-making procedures incorporate the results of all the analyses, together with information on hurricane forecasting parameters and errors, which provides local emergency management officials an aid in deciding whether and when to evacuate.

The final products of an HES are the information contained in the technical data report and its appendices and any maps, charts, diagrams, decision-making tools, or other study products that will enhance the usefulness of the data developed in the study. Study Managers should assist state and local officials with producing new or revised evacuation plans and a public information program.

Several study products lend themselves well to computer formats, which can greatly enhance their presentation, reduce the chance of error when manipulating data under stressful circumstances, and lower the costs of revisions and updates. While the HES program should not be used as a funding vehicle for providing and/or expanding a Geographical Information System (GIS), to the maximum extent possible, all study data should be developed in a digital format. If state or local GIS capability does exist, study data should be compatible with existing software.

b. Coordination.

A hurricane evacuation involves several governmental agencies and private organizations performing such functions as storm warning, evacuation decision making, communications, traffic control, and shelter management. These agencies and organizations also have an indispensable role in hurricane preparedness planning. A state-of-the-art HES can provide the best possible technical data, but only elected officials, emergency management officials, and others who must ultimately put an evacuation plan into action can ensure that the plan is implementable. Those persons having state and local emergency preparedness responsibilities should participate in every step of the study by reviewing data gathered and generated, providing suggestions for more useful study products, and by anticipating potential problems with implementing the various aspects of evacuation plans.

The ultimate decision to evacuate an area is usually left to the elected officials in charge of that jurisdictional unit, who are advised by the local Director of Emergency Management. Since those officials are held responsible for hurricane evacuation planning and decision making, it is especially important that they are familiar with the study from its outset; however, they seldom seek involvement with the study process or products. **The Study Manager and technical consultants should, to the greatest extent possible, ensure the participation of key personnel by maintaining an exchange of data and ideas. Personal contacts and group meetings are the preferred means of communication.** Time constraints will sometimes preclude these methods and the Study Manager's coordination techniques should remain flexible, using alternative means of communication for methods that prove to be less than satisfactory. Regardless of their degree of participation, all key personnel should be kept abreast of the progress of the study, possibly through bulletins or newsletters. This will not only further their understanding of the magnitude of the study effort, but will lend credibility to the study results.

The close coordination that is necessary to a successful HES poses a challenge to the study manager. For previous studies, a tri-level coordinative mechanism has been used to provide maximum flexibility, ensure proper and thorough data gathering, and allow for unencumbered exchange of information. A description of the traditional coordinative structure follows:

(1) Interagency. Communication between the Federal, state, and local agencies involved with the study should be unencumbered. The Study Manager should keep all Federal and state agencies abreast of the progress of the study through frequent oral communication and formal status reports. State emergency management agencies should be encouraged to develop a communications network through which a two-way flow of information can be maintained with local emergency management officials. Routine correspondence can be disseminated directly to local officials through memoranda, letters or newsletters with information copies to state officials. It is especially important to maintain close coordination with the FEMA Regional Program Manager. He/she should be furnished copies of pertinent correspondence, contractor reports, draft reports, etc., and should be consulted on schedules for all meetings, workshops, or other study related activities. Additionally, study progress

should be reported to the FEMA Regional Program Manager through reports submitted within 30 days of the end of each fiscal quarter.

(2) Disaster Preparedness Committees. The Disaster Preparedness Committees should consist of state and local emergency management officials, local elected officials, the local NWS office, the American Red Cross, and key personnel of other agencies and organizations, primarily at the county, township, and city level, who have direct responsibility and authority in some aspect of hurricane emergency operations or planning. These officials represent agencies and organizations that include city councils and county commissioners, state and local law enforcement, fire departments, school boards, and departments of social services. Members of the various news media should be invited to attend the committee meetings. The primary purposes of the Disaster Preparedness Committees are to provide important data for the study and to review appropriate study products. Since the committee members will be the "users" of the information generated by the evacuation study, their meetings can provide the forum needed to explain the methodologies and products of the various study analyses and to offer comments. Meetings should be held at major milestones in the study to gather essential information, to present the results of completed analyses, to describe the relationships of the major analyses, and to review the progress of the study. To the greatest extent possible, technical consultants contributing to the study should personally present the results of their analyses to the Disaster Preparedness Committees. These presentations by experts in their respective fields enhance the credibility of the study results.

(3) Executive Committee. Officials from the principal participating agencies should be asked to serve as members of the Executive Committee. Membership should include an appropriate USACE official at division level, a designated representative of the FEMA Regional Director, and a representative of the state requestor. The Executive Committee should convene as needed to review the progress of the study, to discuss and plan for future study tasks, and to ensure the interagency coordination that is vital to the HES effort.

c. Hazards Analysis.

(1) Hazards of Coastal Storms. The purpose of the hazards analysis is to quantify the wind speeds and still-water surge heights that could be produced by a combination of hurricane intensities, approach speeds, approach directions, and tracks considered to have a reasonable meteorological probability of occurrence within the study area. Potential freshwater flooding from rainfall runoff is evaluated, based on

available information. Since extratropical storms can also dramatically affect coastal areas with abnormally high winds and resultant high water levels, they are also included in this analysis and addressed to the level necessary to define their impacts in the study area.

(2) Storm Surge. Storm surges are higher than usual water levels along coastlines and the shorelines of bays and estuaries that result from large-scale meteorological disturbances. **Along the mid-Atlantic seaboard, extratropical storms called "nor'easters" have produced some of the highest storm surges and accompanying damages in recent history. However, minimal hurricanes can produce even higher surges and intense hurricanes, with their vast energy and relative compactness, have the potential to produce unprecedented water levels.**

As the wind blows over the surface of the water, it exerts a horizontal force that induces currents in the same general direction. These currents are the primary cause of storm surge. Depending upon the intensity of the wind and forward motion of the storm, the depth affected by this process can reach several hundred feet. When these horizontal currents are impeded by a sloping continental shelf, the water level begins to rise. The amount of rise increases shoreward to a maximum level that is often inland from the usual shoreline. Because of the size and forward speed of hurricanes, the duration of peak surge is normally less than one tide cycle. However, if a storm stalls or is slow-moving, the peak surge duration may be extended considerably.

Extratropical storms are usually slower moving and have less intense winds than hurricanes but are considerably larger, usually affecting a much longer reach of the coastline. Because of their relative size and motion, extratropical storms also prevail for longer periods at a particular location. Their resulting surge is not so much a function of extraordinarily high winds and rapid forward motion but more the effect of sustained gale force winds blowing landward or parallel to the coast over an extended period of time, often for several tide cycles. The surge tends to build gradually, reaching higher levels with each astronomical high tide, but with far less potential for catastrophic flooding than an intense hurricane.

(3) Wind Hazards. Although most casualties of hurricanes and extratropical storms are victims of storm surge, wind hazards accompanying these storms are not to be ignored. Hurricanes Hugo (1989) and Andrew (1992) have demonstrated the widespread devastation often caused by violent winds in intense storms.

According to the American Society of Civil Engineers publication ASCE 7-88, July 1990, "Minimum Design Loads for Buildings and Other Structures," at a height of 140 feet, design wind pressures should be increased by 50 percent; at 200 feet, increased by 70 percent; and at 350 feet, increased by 100 percent. The implications for tall buildings and high-rise bridges are quite clear. In the case of tall buildings that may be considered safe havens from hurricane winds and surge, the following factors can result in catastrophic failure of building components that results in serious injury and/or loss of life to occupants. Not only are wind velocities and pressures usually higher at upper floors, but suction effects at critical points on the structure can be twice as great as the maximum direct force on the windward face (Proceedings of the American Society of Civil Engineers, Journal of the Structural Division, Vol. 102, No. ST1, Jan. 1976, "Window Glass Failures in Windstorms," Minor and Beason). Additionally, sudden failure of windows or doors can momentarily increase internal pressures by as much as 80 percent (Proceedings of the American Society of Civil Engineers, Journal of the Engineering Mechanics Division, Vol. 107, No. EM2, April 1981, "Building Internal Pressure: Sudden Change, "Liu and Saathoff).

A major consideration for high-rise bridges is the fact that they will not only experience considerably higher peak velocities than at the surface, but sustained tropical storm winds (the cutoff point for evacuation) will arrive at those heights prior to occurring at ground level. Hurricane preparedness planning should include the likelihood that high-rise bridges will close before roadway traffic is curtailed at ground level.

Recently, NOAA's Hurricane Research Division has developed a model for predicting inland winds associated with landfalling hurricanes along the Gulf of Mexico and the Atlantic coast as far north as North Carolina. A similar model is expected to be forthcoming for the mid-Atlantic states. This model accounts for wind speed decay as hurricanes move over land from the water. Applications of the model are expected to include real-time forecasting of inland winds and hypothetical estimates of maximum inland penetration of hurricane-force winds. Study Managers should ascertain the status of the inland wind model and its applicability to the area being studied.

(4) Forecasting Errors. Hurricane (and extratropical storm) forecasting is not an exact science. An analysis of hurricane forecasts made by the NHC indicates the normal magnitude of error. From 1976 to 1990, the average error in the official 24-hour hurricane track forecast was 140 statute miles. The average error in the 12-hour official forecast was 70 miles. During the same time period, the average error in the official 24-hour wind speed forecast was 15 miles per hour (m.p.h.), and the average error in the 12-hour official forecast was 10 m.p.h. Decision makers should be

aware that an increase of 10 to 15 m.p.h. can easily raise the intensity value of an approaching hurricane one category on the Saffir/Simpson Hurricane Scale (developed by Herbert Saffir and Dr. Robert H. Simpson). For this reason, officials who are faced with an imminent hurricane emergency should consider preparing for a storm one category higher than the strength forecast for landfall. Because of the uncertainties in hurricane forecasting, a worst-case approach is taken for wind and surge hazards in conducting evacuation studies.

SAFFIR/SIMPSON HURRICANE SCALE RANGES

Scale Number Category	Central Pressure Millibars	Central Pressure Inches	Winds (Mph)	Winds (Kts)	Damage
1	≥ 980	28.94	74 - 95	64 - 83	Minimal
2	965 - 979	28.50 - 28.91	96 - 110	84 - 96	Moderate
3	945 - 964	27.91 - 28.47	111 - 130	97 - 113	Extensive
4	920 - 944	27.17 - 27.88	131 - 155	114 - 135	Extreme
5	< 920	< 27.17	> 155	> 135	Catastrophic

(5) The SLOSH Model. The primary objective of the hazards analysis is to determine the probable worst-case effects from the various intensities of hurricanes that could strike the region. The study identifies "worst-case effects", i.e., the peak surges, wind speeds, and wave effects that can be expected at all locations within the study area, regardless of the point of hurricane landfall. The NHC uses the SLOSH numerical model to determine the timing, severity, and sequence of wind and storm surge hazards that can be expected from hurricanes of various intensities, tracks, and forward speeds striking the study area, computing the potential effects of many hundreds of theoretical hurricanes. In the modeling, the NHC uses hurricane parameter values determined to be the most meteorologically probable for the study area. "Still-water" surge heights, wind speeds, and wind directions are calculated by the

SLOSH model for several thousands of grid squares and printouts of that data are provided for up to 120 selected "critical point" locations. Local processes, such as waves, astronomical tides, and rainfall-induced flooding are usually included in observations of "storm surge" height, but are not surge-related and are not calculated by the SLOSH model. The effects of these processes combined with storm surge are sometimes called "storm tide".

(6) Maximum Envelope of Water. Effective evacuation planning and decision making require a means of compensating for inaccuracies in hurricane track forecasting. The Maximum Envelope of Water (MEOW) developed by the NHC provides a good form of condensation by eliminating any consideration of hurricane track. Coincidentally, the MEOW greatly simplifies the planning and decision-making processes by reducing the number of variables that must be considered.

During the passage of a hurricane, the highest surge reached at each location within the affected area is called the maximum surge for that location; the highest maximum surge is called the peak surge. The location of the peak surge depends upon where the eye of the hurricane crosses the coastline, hurricane intensity, bathymetry of the basin, configuration of the coastline, approach direction, and radius of maximum winds. To compensate for one major inaccuracy, track forecasting, the potential peak surges for all locations, regardless of track, are determined. MEOW's were specifically developed for this purpose. They are compiled by the NHC from a large array of peak surges calculated for the many individual hurricanes modeled. They consist of computer printouts showing peak surge values developed for each combination of category, approach direction, and approach speed modeled. For example, if 5 hurricane intensities, 5 approach directions, and 2 approach speeds were used in the SLOSH computations, 50 MEOW's will be produced. The values contained in the MEOW's are the peak surge height values for each location regardless of where hurricane landfall may occur.

(7) MOM's. "MEOW's of the MEOW's" (MOM's) are further combinations of MEOW's. As in the case of MEOW's, the purpose of preparing MOM's is to compensate for forecast inaccuracies and to simplify hurricane evacuation planning and decision making. MOM's can be created by the NHC by extracting the highest peak surge values from two or more MEOW's. By using the highest peak surges for two or more intensities, approach directions, or approach speeds, the effects of forecast inaccuracies and the number of considerations in hurricane evacuation planning are further reduced (see Vulnerability Analysis, Inundation Maps). However, there are also converse effects. Each combination of MEOW's reduces the specificity of the

SLOSH results by retaining only the highest peak surge values of the combination. Thus, care should be taken to note whether peak surge values of the MOM's are outliers, and to ensure that they reasonably represent all the peak surges contained in the collective MEOW's.

(8) Adjustments to SLOSH Model Values.

(a) Statistical Analysis. Hurricane evacuation planners and decision makers should keep in mind that SLOSH is a mathematical model that cannot perfectly replicate nature. The accuracy of the SLOSH model has been evaluated using parameters of historical hurricanes to hindcast the surge heights measured after those storms. Based on a statistical analysis conducted by the NHC, adding 20 percent to the computed SLOSH surge values would eliminate most of the potential negative errors. However, such an adjustment would also add additional surge height to those values that already contain positive errors, possibly endangering the credibility of the SLOSH results. With this in mind, surge heights produced by the SLOSH model traditionally have not been adjusted. If the computed values are accepted, decision makers should remember that some SLOSH surge heights could understate the potential surge by as much as 20 percent.

(b) Astronomical Tide. Since the datum used in the SLOSH model is National Geodetic Vertical Datum (NGVD), formerly known as mean sea level of 1929 (m.s.l.), an astronomical tide level above NGVD would add additional height to the values computed by the SLOSH model. The potential effect of the phasing of astronomical tide with the occurrence of hurricane storm surge can be quite dramatic or of little consequence, depending on the normal tide range. Any astronomical tide height above the mean will add directly to the total or "storm tide" level. Accordingly, the potential effects of astronomical tide should be recognized and evaluated. Emergency management officials should elect either to accept the computed surge heights or to make a general adjustment to those values for astronomical tide. The concerns in making this adjustment are similar to those related to SLOSH inaccuracies. The magnitude of the tide range and the potential consequences of adding the appropriate value to the calculated surge heights should be carefully considered. In some study areas, officials have elected to compensate by adding a value for astronomical tide while in other areas compensation will be handled on a case-by-case basis when a hurricane emergency is imminent. Using the later approach, the hypothetical surge heights would be adjusted only if forecasts indicate that the impending storm surge will occur coincidentally with an astronomical high tide.

(c) Wave Effect. The SLOSH model does not provide data concerning the additional heights of waves generated on top of the still-water storm surge. Generally, waves do not add significantly to the total area flooded by storm surge and can usually be ignored, except for locations immediately along the open coastline or the shorelines of very large sounds and estuaries. In these areas, wave crests can increase the expected still-water depth above the terrain significantly, greatly increasing the hazard. Since near-shore wave phenomena under hurricane conditions are not well understood, it is assumed that, along the open coast, maximum theoretical wave heights occur near the time of landfall. Due to the presence of structures, dunes, or vegetation, the waves usually break and dissipate a tremendous amount of energy within a short distance of shore. Structures within that zone are often heavily damaged or destroyed if not specifically designed to withstand the forces of wave action. High velocity "V Zones" are shown on Flood Insurance Rate Maps (FIRM) of the National Flood Insurance Program (NFIP) where waves higher than three feet with a one percent annual chance of occurrence are expected.

For planning purposes, it is also important to consider potential wave effects prior to the arrival of sustained tropical storm winds, at which time the evacuation is theoretically complete. Before making calculations of wave height and run-up at critical locations within the study area, surge heights at the time of arrival of sustained tropical storm winds should be considered. The rationale is to determine if wave action above still-water surge heights will aggravate the flooding of roads, bridges, or other critical areas near the coastline, thereby increasing the prelandfall hazards times.

(9) <u>Time-History Data</u>. In the SLOSH model, up to 120 geographic "critical points" can be designated for time-history tabulations of surge height and wind speed that are valuable in hurricane preparedness planning. These tabulations can be used for timing evacuations, sheltering, and traffic control. "Critical points" are usually selected at a special meeting of NHC and emergency management officials prior to commencing the SLOSH model storm simulations. They are chosen to coincide with locations where flooding would probably first curtail an evacuation, low-lying roads and bridges; at potentially vulnerable population centers; and at significant natural or manmade barriers. The time-history information produced by the SLOSH model lists values at each "critical point" for still-water surge height, wind speed, and wind direction. Values are listed at 30-minute intervals for periods ranging from 30 hours for fast moving hurricanes, to 72 hours for slow moving hurricanes.

One purpose of the time-history data is to determine hypothetical prelandfall hazards times for each designated SLOSH "critical point". Prelandfall hazards time is the period of time prior to hurricane eye landfall when an evacuation would be curtailed due to the arrival of sustained tropical storm winds (34-knot sustained wind speed, 1-minute average). Total evacuation times are based on hurricane eye landfall and are calculated by adding hypothetical prelandfall hazards times to the clearance times determined in the transportation analysis (see Transportation Analysis, Calculated Clearance Times).

Along the Gulf of Mexico and Atlantic coasts, numerous communities on barrier islands are connected to the mainland by low, bridged causeways. Many other coastal residents depend on transportation routes that extend across extensive coastal lowland marshes and swamps. Storm surge inundation of those low-lying roads would severely curtail their use as evacuation routes. Using the time-history data furnished by the SLOSH model, the study manager can evaluate the potential for inundation of low-lying roadways prior to the arrival of sustained tropical storm winds. To do so, he/she should note for each "critical point" the still-water surge height at the time of arrival of tropical storm winds and make any necessary adjustments for wave effects and astronomical tide. If topographic information shows that significant flooding could occur, prelandfall hazards times should be adjusted accordingly.

Time-history data can also be used to determine the maximum sustained wind speeds that can affect specific locations, regardless of whether they are subject to storm surge. Although the SLOSH model does not calculate wind gusts, sustained wind speed information could be extremely valuable in areas at high risk to wind damage.

(10) Rainfall Flooding. Potential freshwater flooding from rainfall accompanying hurricanes must also be evaluated. However, due to the wide variation in amounts and times of occurrence from one storm to another, rainfall can only be addressed in general terms. For most hurricanes, the heaviest rainfall begins near the time of arrival of sustained tropical storm winds; however, heavy rains in amounts exceeding 20 inches can precede an approaching hurricane by as much as 24 hours. Unrelated weather systems can also contribute significant amounts of rainfall within a basin in advance of a hurricane. Potential rainfall flooding can be best evaluated by identifying areas and facilities that have historically been flooded by heavy rainfall. Interviews with emergency management personnel and other local officials familiar with flooding problems are an effective means of accomplishing this. FEMA flood insurance study reports, USACE flood plain information reports and basin studies, and similar publications can also be used to estimate rainfall flooding problems. To the

extent possible, roads that show potential for inundation should not be considered for evacuation routes or shelter access in the transportation analysis.

(11) Extratropical Storms. Where appropriate, hurricane evacuation studies should address extra-tropical storms. The historical severity of "nor'easters" in the mid-Atlantic and New England states necessitates including them in any treatment of coastal storms. The drowning of thirteen persons from storm surge on the Florida Gulf coast in a March 1993 extratropical storm points to the need to also address extratropical storms in other areas. Hurricane evacuation studies should include, at a minimum, a discussion of extratropical storms and a comparison of associated surge levels to potential hurricane surge.

d. Vulnerability Analysis.

(1) General. The purpose of the vulnerability analysis is to identify the areas, populations, and facilities that are potentially vulnerable to flooding and extraordinary wind damage under a variety of hurricane threats. While the hazards analysis provides information on the magnitude and timing of potential hurricane events, the vulnerability analysis identifies the wind and flooding impacts on vulnerable areas. Storm surge data and rainfall inundation information from the hazards analysis are used to develop inundation maps, evacuation scenarios, and evacuation zones; to quantify the population at risk under a range of hurricane conditions; and to identify major medical/institutional and other facilities that are potentially vulnerable to flooding.

(2) Inundation Maps. The purpose of the inundation maps, sometimes called storm surge atlases, is to depict the limits of the potential flooding from the peak surge values computed by the SLOSH model. The primary use of these maps is to determine which surge vulnerable areas may need to be evacuated in response to a particular coastal storm threat. The inundation maps have proven quite useful to emergency management officials, the NWS, the American Red Cross, and others involved in evacuation planning. Increasingly, private businesses and utilities are requesting vulnerability information and copies of the maps. The demand for these maps should not be underestimated. For some studies several hundred copies have been printed.

Areas of potential inundation, henceforth referred to as vulnerable areas, should be delineated on topographic maps or elevation grids using peak surge values from the MOM's developed during the hazards analysis. The peak surge heights used for the mapping should include any adjustments made to the SLOSH values (see "Adjustments to SLOSH Model Values"). If appropriate, consideration should also be given to mapping potential storm surge from extratropical storms. Depending upon the characteristics of most extratropical storms affecting a given study area, a cross-reference to the effects of Category 1 or 2 hurricanes may be appropriate.

The following is a traditional technique for delineating inundation areas using SLOSH model output:

(a) Obtain transparent overlays of the SLOSH model geographic grid at the appropriate scale for the topographic maps to be used (usually 1:24000 to overlay U.S. Geological Survey quadrangle maps).

(b) Transfer elevation data from the SLOSH output for each grid to the transparent overlays.

(c) Determine flood inundation limits for each grid by comparing flood elevations from the SLOSH output with topographic contours on the base maps, and draw the flood inundation lines on the transparent overlay.

(d) Determine the preliminary inland limits of the vulnerable areas for the evacuation scenarios on a separate transparent overlay using recognizable streets, highways, railroads, and natural barriers as boundaries (see Evacuation Scenarios).

Vulnerable areas have traditionally been delineated according to storm surge height for various hurricane intensities. These delineations provide the initial indication of populated areas that would have to evacuate under a given hurricane threat. Some studies have provided separate delineations for all five hurricane categories of the Saffir-Simpson Scale and further segregated storm effects according to forward speed or approach direction. However, in the interest of simplifying the inundation mapping, all studies have used MOM's to some degree to combine categories and/or speeds and directions. The logical parameters to combine into MOM's primarily depend upon a comparison of the MEOW's for surge heights and preliminary vulnerable areas. Combining MEOW's into MOM's for the inundation mapping is appropriate when there are minimal differences in surge heights or preliminary vulnerable area boundaries. When these factors vary to a great degree, the hurricane parameters (intensity, forward speed, and approach direction) should remain separate variables (see Hazards Analysis, MOM's).

Inundation maps should be produced in a digital format in order to accommodate current or future Geographic Information Systems (GIS). Digital mapping (as well as other study products) should be developed with a non-proprietary format which is easily supported by the leading market software packages. In light of the wide variety of base mapping available for different study areas, no one standard should be established other than " the best available" that is compatible with the needs of the principal users. Because of the rapid advances taking place in digital mapping, study managers should make an earnest effort to acquaint themselves with mapping techniques used in recent studies and in similar projects. This will help control costs and ensure creation of superior products.

Once the vulnerable areas for each MOM have been delineated on topographic maps, that information should be presented on base maps. If high quality digitized maps are not available, new digitized base maps should be prepared from the best available hard-copy mapping. It is important that all study sponsors agree on the appropriate level of sophistication for the inundation mapping. Progress in the availability and affordability of computer mapping may, in the near future, provide additional options for base maps and, possibly, for the delineation of vulnerable areas based on an actual hurricane threat. Again, the Study Manager should be abreast of current mapping techniques that may be applicable to his/her study area.

Hard-copy inundation information can be portrayed in several ways. Every study should have an atlas of suitable scale maps produced as an appendix to the technical data report. Also, large-scale wall maps can be printed for use in emergency operations centers, for training purposes, and for public display.

(3) Vulnerable Population. The vulnerable population is comprised of all persons residing within the area subject to storm surge and the residents of mobile homes located above expected flood levels. It is important to note the special provisions for those living in mobile and manufactured homes. Because of their greater vulnerability to the strong winds associated with hurricanes, all mobile and manufactured home residents are advised to evacuate regardless of their location within the study area.

To determine the vulnerable population, the most recent permanent and tourist population data should be obtained and projected to the expected study completion date. U.S. census data is usually available by tract or enumeration district for numbers of residents, mobile homes, vehicles per household, etc. Some of the more densely populated areas have developed traffic analysis zones for which similar population data is available. For advanced planning purposes, a preliminary estimate of the vulnerable population for each hurricane threat situation can be obtained by comparing the appropriate map of census tracts, enumeration districts, traffic analysis zones, or other population data base to the inundation information and totaling the population within the flooded areas. The number of mobile and manufactured home residents and the number of affected tourists must also be included. Consideration should be given to evacuation participation percentages developed in behavioral analyses. To take a conservative approach, some jurisdictions have assumed 100 percent participation. Final estimates of the numbers of evacuees (for use in the Transportation Analysis) are based on evacuation zone boundaries.

(4) Evacuation Scenarios. Hurricanes with quite different parameters can have virtually the same flooding impacts on a community. The hurricane evacuation scenarios depict the similar effects of unlike hurricanes. The scenarios are combinations of MOM's (hurricane intensity, approach direction and forward speed) that affect essentially the same population, delineating successive additional areas that will need to be evacuated. Following the initial development of the MOM's for the inundation mapping, further combinations of hurricane parameters are possible based on population distribution. Combinations that involve small population percentage changes may be appropriate. Care should be taken to ensure that the final scenario delineations accurately reflect the operational intentions of local emergency management officials by describing the areas that the community will evacuate concurrently. In some locations, such as barrier islands, a partial evacuation may not be practical. This stage of the evaluation is critical and requires care, diligence, and common sense in the delineation of realistic and probable scenarios. Community emergency management coordinators and other local decision-making officials should be consulted to ensure that the scenarios realistically represent evacuation plans. Because the evacuation scenario designations are critical to the transportation analysis, the scenarios should be developed in the early stages of that analysis.

Since the scenarios will be subdivided into evacuation zones, their delineation should be based on the vulnerable areas shown on the inundation maps and population data. Primarily, evacuation scenarios are developed by approximating the various flooding limits shown on the inundation maps along census tract or other data base boundaries. The flood inundation limits will not follow streets and highways in a consistent manner. The lines will fall between or across geographic features and generally meander throughout the study area. However, delineations should be kept as simple as practicable using major natural or manmade geographic features and should conform to existing political or demographic boundaries (i.e., counties, townships, villages, census tracts, enumeration districts, zip codes, or traffic analysis zones). Study Managers should remember that the shelter demands and clearance times computed later for each scenario will be directly related to these delineations and their associated populations.

(5) Evacuation Zones. A network of zones must be established that covers the entire study area. The purpose of evacuation zones is to geographically locate and quantify the vulnerable population, provide a base to model traffic movements from one geographic area to another, determine needed shelter capacity, and facilitate future updating. Since wind-vulnerable housing units will be quantified, evacuation zones should subdivide the areas above expected flood heights as well as those covered by the inundation scenarios. For operational use, zones developed for the transportation analysis may be combined or further divided, depending on the desires of local emergency management officials. Because of the close relationship of this task with the transportation analysis, zone boundaries are usually delineated in conjunction with that analysis.

Evacuation zones should be established based on the following factors:

(a) Relate to expected flooding limits (based on inundation maps).

(b) Relate well to census districts, traffic analysis zones, or other data base units.

(c) Should be established, if possible, to facilitate evacuation orders or advisories.

(d) Boundaries should, to the extent possible, coincide with identifiable natural geographic features, roadways, railroads, landmarks, etc.

(e) Zones that would be isolated by surrounding surge should be avoided.

(f) Should be served by major evacuation routes.

(g) Should have relatively balanced populations.

(h) Must allow for appropriate transportation modeling.

(6) Institutional and Medical Facilities. Evacuation plans should include detailed information on the vulnerability of institutions and medical facilities to hurricane hazards. The purpose of this analysis is to determine the institutions and medical facilities that will require evacuation under various hurricane threats. Primary considerations include their proximity to vulnerable areas, exposure to extreme winds, and inundation of access routes. A complete inventory of institutions and medical facilities with their capacities should be compiled for the study area. This should include hospitals, nursing homes, retirement homes, family care homes, jails, prisons, etc. The Study Manager should request rosters of such facilities from state and local departments of human resources or social services. Each facility should then be located on the inundation maps. This may require the assistance of local emergency management or social services officials. For facilities lying in or near vulnerable areas, the Study Manager should accurately determine the first floor elevation in reference to NGVD and evaluate the vulnerability of access routes to flooding. Those officials responsible for designating public shelter facilities should determine the survivability of existing emergency utility systems (i.e., emergency generators, water pumps, etc.). The technical data report should contain a complete roster of facilities that are vulnerable to flooding, their capacities, and a comparison of their first floor elevations to potential surge levels.

In order to evaluate all types of facilities in an efficient manner, the vulnerability of public shelters to flooding should be determined coincidentally with the vulnerability of institutions and medical facilities (see Shelter Analysis).

(7) Public Transportation Demand. To the extent possible, population data developed for each evacuation zone should include an estimate of the numbers of persons who do not have access to a private vehicle and, consequently, would have to rely on public transportation in an evacuation. This data may be available through the U.S. Census. The transportation analysis should include a comparison of public transportation demand versus availability, and the clearance times reflect any expected delays. Local evacuation plans should provide for needed public transportation.

(8) Special Emergency Transportation Needs. While transportation for the elderly and infirm residing in Special Needs (health-related) facilities should be the responsibility of the individual facilities, provision of adequate special emergency transportation for those in private homes is usually a responsibility of local emergency management officials. Institutions should be encouraged to develop comprehensive, coordinated hurricane evacuation plans that include when to leave, specific

destinations, and pre-arranged transportation.

An evaluation of the demand for special emergency transportation can be initiated early in the study. Emergency management officials should plan to provide the transportation capacity necessary to satisfy this demand within the calculated clearance times. Detailed information concerning residents of private homes may be difficult to obtain initially and nearly as difficult to update. However, the numbers of persons residing in private homes that would require public assistance in an evacuation should be determined as closely as possible. Each local government should develop procedures for maintaining an up-to-date roster of persons likely to need special public transportation assistance. Every reasonable effort should be made through departments of social services; health agencies; newspaper, radio, and television queries; or other means to account for everyone.

Types of emergency transportation should be matched to any special needs for assistance. Non-ambulatory patients will require transportation that can easily accommodate wheelchairs, stretchers, and, possibly, life support equipment. Lack of planning for sufficient appropriate equipment will result in critical evacuation delays and increased hazards for the evacuees.

e. Behavioral Analysis.

(1) General. In preparing hurricane evacuation plans, assumptions must be made regarding the manner in which the population in and around the vulnerable area will react to the threat. These assumptions are necessary for shelter planning, transportation modeling, and guidance in evacuation decision-making and public awareness efforts. The results of the behavioral analysis should be expressed in standardized terms to provide direct, compatible input for the transportation analysis.

Public response to hurricane threats has clearly and conclusively been shown to vary with the specific circumstances of the threat and with the public's perception of the advice of local officials. Therefore, reliable forecasts of people's responses to hurricane threats cannot be made solely, or even primarily, from their answers to survey questions about hypothetical situations. Survey data can provide a starting point from which behavioral predictions can be made. One effective approach has been to collect survey data, compare the responses to survey results from other locations, and then interpret the predictive validity of the responses in light of what is known to have occurred in actual threats. The behavioral analysis should be structured to utilize a combination of results from surveys conducted with residents and tourists in the study area and in other coastal areas and from studies of actual public response in past hurricane threats. Prior behavioral analyses have included telephone surveys of area residents and personal interviews with tourists.

Because of the intricacies involved in composing sample surveys and interpreting the responses, the behavioral analysis should be conducted only by individuals having expertise in sociology, social psychology, or behavioral geography, and mass survey techniques specializing in the hazards field. The analyst should have experience with projects that generated quantitative forecasts of mass behavior. A professional survey organization should perform the data collection, preferably by telephone.

(2) Objectives. The specific objectives of a behavioral analysis are to determine the following:

(a) The percentage of the vulnerable and nonvulnerable population that will evacuate under a range of hurricane threat situations. It is known that a number of people who have substantial housing and are not threatened by flooding will evacuate along with the vulnerable population.

(b) When the evacuating population will leave in relation to an evacuation order or advisory given by local officials or others in authority.

(c) The probable destinations of the evacuees, expressed as percentages of the total number, who would go to local public shelters, remain in the local area with friends or relatives, remain in the area in a hotel or motel, or leave the area for out-of-region shelter.

(d) The percentage of available vehicles that the evacuees will use for hurricane evacuation.

(e) The percentage of the total number of evacuating vehicles that may be motor homes or towing boats, campers, or other equipment.

(f) How the population will respond based on forecasts of hurricane intensity, probability, or other information provided during a hurricane emergency.

(g) The evacuation response of tourists.

(h) The percentage of evacuees who would require public assistance for emergency transportation.

(3) Burden Hour Authorization. Estimates of the number of hours the public would be burdened by answering questions for the behavioral survey must be submitted to the Office of Management and Budget (OMB) through HQUSACE and FEMA. For recent studies, FEMA and OMB have provided a blanket authorization for these surveys. Study Managers should be aware that surveys cannot proceed without the proper authorization and that obtaining an individual authorization, if required, can take several weeks.

(4) Effective Communication. Because of the substantial variation in the public's reaction to hurricane threats based on their perception of the specific circumstances and the advice of local officials, technical data reports should highlight the importance of effective communication of evacuation orders and advisories in prompting appropriate public response.

f. Shelter Analysis.

(1) General. The purposes of the shelter analysis are to estimate the number of evacuees that will seek public shelter and the number of shelter spaces available, and to provide information for use in determining evacuation clearance times in the transportation analysis. The shelter analysis should address shelter locations, capacities, demand, and potential vulnerability. Data developed in the hazards, vulnerability, and behavioral analyses are used in the shelter analysis.

Potential shelter capacity deficits in several states, most notably Florida, have engendered comprehensive study and analysis of many shelter related issues, including public shelter selection, wind vulnerability, vertical refuge and refuge of last resort. Study managers should seek to acquaint themselves with recent treatment of these issues prior to initiating the shelter analysis.

(2) Public Shelter Inventories and Capacities. The Study Manager should request an inventory of existing public shelters and capacities from the appropriate state or local agency. In some areas this information may be available from the American Red Cross. Often the Study Manager will find that a formal list of predesignated shelters does not exist and available capacity has not been determined. Since obtaining shelter agreements with local school officials or others in charge

of public buildings can be a lengthy process, the Study Manager should investigate the existing situation early on in the study. Although the Study Manager should provide reasonable assistance, it is not a function of the evacuation study to designate public shelters or determine shelter capacities. The USACE may assist with evaluating structures through a least-risk decision-making process, but should not certify any facility as being suitable for use as a shelter. The American Red Cross publication "Guidelines for Hurricane Evacuation Shelter Selection" and subsequent supplements to that document make recommendations for public shelter capacity and safety and define the best means of selecting shelter facilities. Current draft guidelines present a least-risk approach. The Study Manager should obtain the latest version of these guidelines from a local or state Red Cross official.

(3) Potential Vulnerability. The Study Manager should locate the public shelters on the inundation maps, asking local emergency management, department of social services, or American Red Cross officials for assistance, if necessary. He/she should then determine the vulnerability of those shelters and their access routes to flooding. For economy, field surveys needed for the shelter analysis should be conducted concurrently with field work related to institutions and medical facilities.

In some study areas, officials have elected to open shelters in vulnerable areas based on the forecast intensity of an approaching hurricane. For example, some shelters would be utilized for a category 1 or 2 hurricane, but would be unusable during more intense storms. In this case, planners should use the "MOM" approach and evaluate the flood hazard based on the potential peak surge for all approach directions and forward speeds. If shelters are opened according to hurricane intensity, the NHC recommends that officials add one category to the intensity forecast at landfall. When using this approach, numbers and locations of shelter spaces must be appropriately adjusted by scenario for the transportation analysis.

(4) Public Shelter Demand. Public shelter demand (number of evacuees seeking public shelter) should be calculated for each evacuation scenario. Calculations should be based on population data developed in the vulnerability analysis and estimates of the percent of evacuees seeking public shelter established in the behavioral analysis. Consideration must be given to the number of evacuees who would seek hotel/motel spaces versus the expected availability of those spaces. In those areas where tourist occupancy varies appreciably, a range in shelter demand should be established. Rough shelter demand estimates can be presented to local officials for

their concurrence prior to transportation modeling.

Because of the direct effects of the evacuation scenarios on shelter demand and, hence, on the transportation modeling, refined calculations of public shelter requirements are often done during the transportation analysis.

(5) Demand/Capacity Analysis. For every community in the study area, the shelter demand generated by each scenario and tourist situation should be compared to the total available shelter capacity. The comparison should be shown in the technical data report and shortfalls in capacity should be documented and brought to the attention of emergency management and other appropriate officials. Where shortfalls exist, local jurisdictions should consider creating additional shelter capacity by retrofitting existing buildings with shutters, generators, structural modifications, etc. Also, additional public shelter capacity could be provided outside the local jurisdiction in areas convenient to the evacuees or, if such space is unavailable, in "host" communities remote to the evacuating area.

In the transportation analysis, the numbers of evacuees assigned to public shelters should be limited to the capacity available. If shortfalls exist, evacuees that could not be accommodated should be routed to a destination having excess public shelter capacity, possibly to host shelters as mentioned above, or completely out of the study area.

(6) Shelter Assignment. Following completion of the transportation analysis, each evacuation zone could be assigned to specific public shelters. Although shelter assignments may serve to minimize clearance times in areas where shelter space is critical, in other areas the effects could be negligible.

(7) Vertical Evacuation and Refuge. Vertical evacuation is the preplanned relocation of occupants of vulnerable areas to the upper levels of specifically identified and assigned multi-story buildings. Vertical refuge is the similar relocation of those occupants because of inadequate time or opportunity for them to leave the area. In that case, the action is one of last resort, when multi-story structures offer the only hope of escaping unharmed. Because of safety and legal issues, vertical evacuation or in-place sheltering in tall buildings should not be planned as an alternative, or as a supplement, to horizontal evacuation. Planning for limited vertical evacuation could cause potential evacuees to place undue reliance on the availability of those shelters. However, in some locations vertical refuge in multi-storied structures may offer the

only hope for a portion of the population to escape hurricane inundation. The existence of vertical refuge should not be publicized in advance but could provide an opportunity to utilize multi-story buildings as last resort shelters in an extreme emergency.

g. Transportation Analysis.

(1) General. The primary purpose of the transportation analysis is to calculate the clearance times needed to conduct a safe and timely evacuation for a range of hurricane threats. Other purposes are to define the evacuation roadway network and to evaluate traffic control measures/highway improvements for improved traffic flow. Basic assumptions in the transportation analysis relate to storm scenarios, vulnerable populations and their behavioral and socioeconomic characteristics, roadway system and traffic control, and destination locations. The scope of the transportation analysis should include inland roadways and intersections that could create bottlenecks and critical congestion for evacuating traffic. These locations could be outside of the primary study area.

(2) Evacuation Travel Patterns. During a hurricane evacuation, a large number of vehicles must be moved across a roadway network in a relatively short period of time. As pointed out by the behavioral analysis, the number of evacuating vehicles will vary as a function of the intensity of the hurricane, the number of tourists in the area, and certain behavioral response characteristics of the evacuees. Vehicles enter the road network at different times, depending on each evacuee's response to an evacuation order or advisory. Where vehicles leave the roadway network depends on both the planned destinations of evacuees and the availability of acceptable destinations such as public shelters, hotel/motel units, and friends or relatives in nonvulnerable locations. Traffic movements associated with hurricane evacuation have been identified by five general patterns: evacuation traffic totally within a community; from within a community to outside destinations; from outside origins to destinations within the community; through the community from outside origins to outside destinations; and background traffic (preparation for hurricane). Inter-community traffic movements can result in significant regional traffic impacts. The transportation analysis becomes more complex in those areas where several local governmental jurisdictions will be involved in an evacuation effort. During the analysis, all types of traffic movements should be quantified to aid in estimating roadway congestion and associated clearance times.

(3) Analysis Input. Since all hurricane situations differ in some respects, it is necessary to set forth clear assumptions about storm characteristics and evacuee response before transportation modeling can begin. Changes in storm characteristics, particularly intensity, that affect the vulnerability of coastal residents can cause a wide variation in evacuation response. The primary objective of the transportation analysis is the calculation of clearance times, which are based on a set of assumed conditions and behavioral responses. Since the circumstances under which future hurricane evacuations may be conducted vary widely, sensitivity analyses should be performed during the transportation modeling. Those variables having the greatest influence on clearance times should be identified and then varied to establish a logical range within which actual values should fall.

Transportation modeling input data must be developed for each governmental jurisdiction responsible for initiating evacuations and sheltering evacuees. Key input assumptions that affect the transportation analysis are grouped into five areas:

(a) Hurricane Storm Surge Data. Storm scenarios/evacuation zones.

(b) Socioeconomic Data. Current population and housing unit data by subarea (census tract, enumeration district, or traffic analysis zone); mobile home and seasonal/tourist unit data as available and appropriate; vehicle ownership data; income information if available.

(c) Behavioral Analysis. An analysis of the probable behavioral response characteristics of the population focusing on expected percentages of participation by the population, destination types, rate of response, and vehicle usage.

(d) Sheltering Information. Public shelter and hotel/motel capacities and locations; local emergency management and American Red Cross operational policies affecting timing and/or capacity.

(e) Roadway Network Information. Number of travel lanes by direction per roadway segment, intersection characteristics and operations, bridge locations and operations, traffic count data, and evacuation traffic control assumptions.

(4) Transportation Modeling Methodology.

(a) General. The transportation analysis is necessarily broad in scope, usually

requiring complex computer modeling techniques. Although
metropolitan areas have organizations with the capability of
transportation studies within specific jurisdictions, a regional
can usually be conducted more effectively by a consulting fir
modeling procedures directly applicable to hurricane evacuat
should recognize multiple origins and multiple destinat
consistent with the accuracy of the modeling input data
Although valid transportation modeling methodologies and t
to differ, the following methodology, described in general ter
produce estimates of clearance times that compare favorably
under actual hurricane evacuation conditions.

(b) Evacuation Scenario Development. Hypothetic
unlike characteristics but similar effects on the study area sh
evacuation scenarios (see Vulnerability Analysis, Evacuation

(c) Evacuation Zone Development. Data gathered
enumeration districts, traffic analysis zones, or other data ba
by evacuation zone (see Vulnerability Analysis, Evacuation Z

(d) Dwelling Unit Data by Evacuation Zone. Popul
vehicle ownership data, etc., collected by census tract, traffic
unit must be allocated to the evacuation zones. This will oft
estimating or judgement for more rural areas where there are
more urbanized areas, traffic analysis zones or census block g
obtained which will be a smaller area than a typical evacuati
require less judgement although some splitting of data units
evacuation zone boundary divides a traffic analysis zone or a
permanent population socioeconomic data will need to be su
seasonal visitors obtained from tourism bureaus, local planni
comprehensive hotel/motel listings.

(e) Evacuation Roadway Network Designation. Ea
hurricane evacuation routes are evaluated. In choosing road
evacuation network, care should be taken to designate only t
expected to flood from rainfall or storm surge while the evac
Ideally, other desirable characteristics are little or no adjacen
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d level of service) is developed for
twork to show intersections or
of travel lanes or other

ered in the vulnerability analysis
produce the total evacuating
ation zone. For each zone,
uld be grouped by destination type
on types are local public shelter,
ion halls, etc.), local hotel/motels,
alculated for each storm scenario
meters to the evacuation zonal data
vacuation zone by destination type
are developed for public shelter
to numbers of vehicles that can be

ip tables showing zone-to-zone
ovements for each destination type
hich zones will fill available public
zones. The assignment of vehicle
other zone should reflect public
ncy management officials. The
urisdiction or study area from each

zone to specific exit points is a function of final destination and available routes. In many hurricane evacuation studies the behavioral analysis provides survey or post-evacuation information that gives statistics about which cities and states people wish to go to as evacuation destinations. This information should be used to develop percentages of evacuees/vehicles that will exit the subject county/jurisdiction at different locations.

The destination of local friend's/relative's homes is the most difficult to define. However, a method as simple as dividing the friend's trip productions from a given evacuation zone equally among five to ten nearby "dry" zones is acceptable. More complex methods have used a gravity model approach and allocated the productions to attraction zones based on the distance of and number of people living in the candidate attraction zones. A social-recreational trip length frequency distribution from the area's metropolitan planning organization planning process may be used for traffic attenuation.

Trip tables are developed by storm scenario and destination type since "safe" attractions will vary by storm intensity and each destination type will have different travel characteristics in terms of location and trip length. The final step in trip distribution is the combination of the four destination type trip tables for a given storm scenario into one total trip table. This table then shows all of the trip zone-to-zone interchanges assumed for that particular storm scenario.

(h) Trip Assignment. This step assigns the trip interchanges for a particular scenario to the coded evacuation road network. Routes servicing zone-to-zone and zone-to-area exit points are loaded with the expected vehicle evacuation movements. In urban areas where alternative routes service the same zone-to-zone pair, it is desirable that the model recognize that portions of that traffic will be on different routes. Typically, trip assignment is done in an iterative manner to arrive at logical relative loadings of traffic on competing routes. Unlike daily traffic patterns where the traffic loadings are in a state of equilibrium as users choose minimum distances and times for their travel movements, hurricane evacuations tend to be much more inefficient in their use of available routes. When assigning traffic to routes, the analysis should examine the load balance between key roadway facilities and evaluate positive influences traffic control measures might have on route choice. The result of trip assignment should be tables and/or graphics displaying the number of evacuating vehicles expected to use each route for a given storm scenario. Trip assignments should add evacuation vehicle movements generated external to the subject county/jurisdiction to the tables and route segments as appropriate for a particular scenario.

(i) Calculation of Clearance Times. Evacuating vehicles move at speeds limited by the relationship of traffic loadings on the various roadway segments to the ability of the segments to handle those loadings (roadway capacity). Based on the hourly capacity for each critical link, and the hourly volume desiring to use the link, queuing delay times and evacuation travel times can be calculated. This step meters traffic through the roadway network bottlenecks/critical segments to calculate the time required for all evacuation movements to clear the study area roadways. Various complexities of queuing/traffic flow modeling may be employed depending on the model used. At a minimum, the model should be able to test the effects of different response rates of the evacuating population, different levels of background traffic, and delays due to traffic congestion. In heavily urbanized areas, background traffic will have a dramatic effect on the ability of evacuating vehicles to move through the network. In more rural areas, or urban areas where the surge-vulnerable population is very small relative to the total population, the behavioral response rate will generally be the controlling factor. The end product of this task is a set of clearance times, by local jurisdiction, for each storm scenario (i.e., intensity, seasonal occupancy, level of background traffic/time of day, behavioral response, and/or traffic control option).

(5) Transportation Analysis Products. Although considerable amounts of information are produced in the transportation analysis, the following products are particularly important to hurricane evacuation preparedness and post-storm evacuation assessments.

(a) Evacuation Zone Map. All study area zones are delineated and surge-vulnerable zones are variously shaded to indicate levels of evacuation by scenario.

(b) Evacuation Road Network Map. These maps show the roadways included in the traffic modeling and the relation of the evacuation zones to the road network. They should clearly show the nodes and link names used in the modeling.

(c) Dwelling Unit Data. A listing of census/traffic analysis zone delineations and data with their relation to the evacuation zone system, and a listing by evacuation zone of the number of permanent units, mobile home units, seasonal units, etc., should be provided.

(d) Evacuating People and Vehicle Tables. These tables show the output of the trip generation task. The total number of evacuees and evacuating vehicles produced by every evacuation scenario and tourist occupancy level tested is available for each evacuation zone. The transportation analysis also apportions these numbers by destination type. Public shelter demand should be clearly shown along with key socioeconomic and behavioral parameters that were applied to generate the data. In the technical data report, this information is usually presented as a range for each local jurisdiction exercising authority in hurricane evacuations. The range reflects the effects of testing various storm scenarios and tourist unit occupancies.

(e) Evacuation Road Network Link File. This file shows a link by link listing of assumed roadway characteristics including the number of lanes by direction; if appropriate, a generalized estimate of the link's service volume at a specified level should be given.

(f) Trip Tables by Storm Scenario. For each scenario, this output of the trip distribution task shows the zone-to-zone vehicle movements and the assumed number of vehicles from each zone exiting the county or other jurisdiction at certain points. Due to the quantity of data, consideration should be given to presenting total trip tables in a report appendix and storing trip tables by each destination type on computer disk.

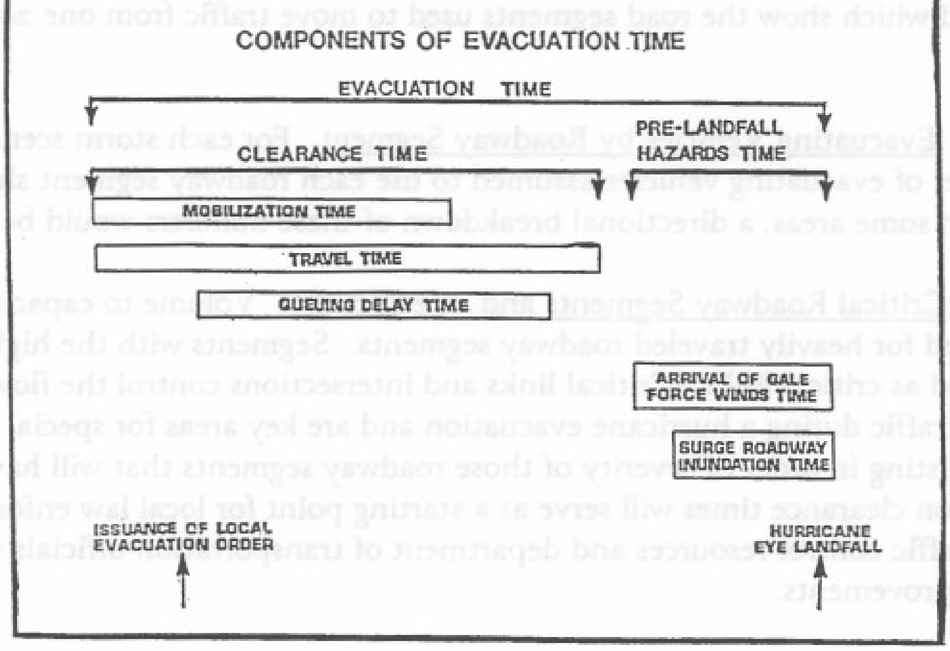
(g) Zone-to-Zone Paths. Depending on the modeling approach, tables should be presented which show the road segments used to move traffic from one zone to another.

(h) Evacuating Vehicles by Roadway Segment. For each storm scenario, the total number of evacuating vehicles assumed to use each roadway segment should be reported. In some areas, a directional breakdown of these numbers would be useful.

(i) Critical Roadway Segments and Intersections. Volume to capacity ratios are calculated for heavily traveled roadway segments. Segments with the highest ratios are identified as critical links. Critical links and intersections control the flow of evacuating traffic during a hurricane evacuation and are key areas for special traffic control. A listing in order of severity of those roadway segments that will have the most effect on clearance times will serve as a starting point for local law enforcement to prioritize traffic control resources and department of transportation officials to plan roadway improvements.

(j) Clearance Time Tables. The most important products of the transportation analysis are the clearance times, which vary depending upon storm scenario; behavioral response; and, if appropriate, tourist occupancy level. The behavioral analysis determines when the evacuees will leave relative to a given evacuation order or advisory (response rate) and the rate at which they will leave. Clearance time is normally estimated for each county. It begins when the first evacuating vehicle enters the roadway network, prior to an evacuation order or advisory, ends when the last vehicle reaches an assumed point of safety, and includes the time spent traveling along the roadway network and waiting due to traffic congestion (queuing delay time). It does not relate to any one vehicle. While the first evacuees are entering the network, others are securing their dwellings and preparing to leave (mobilization time). Clearance time does not include the total amount of time necessary for evacuation decision making, mobilizing government agencies/private organizations, notifying the public, etc.

There is a clear differentiation between clearance time and evacuation time. Clearance time is one component of evacuation time; evacuation time also includes prelandfall hazards time, the time period from the conclusion of the evacuation (as determined by the arrival of sustained tropical storm winds) until the hurricane eye makes landfall, or its closest approach. Thus, evacuation time for a community can be several hours longer than clearance time, as illustrated below.



In estimating clearance times, it is of utmost importance to provide adequate time to safely evacuate the vulnerable population, but the consequences of a premature evacuation order or advisory must also be recognized. Evacuation causes major disruption to the lives of all people affected and, many times, significant adverse economic impacts to business and government. Short clearance times allow more accurate hurricane forecasting and should result in better evacuation decision making. With these factors in mind, clearance times should be estimated as accurately as possible. Factors that affect clearance time should be carefully studied and those having the strongest influence given greater consideration. Sensitivity analyses should be performed by varying, within logical limits, key input parameters such as evacuation scenarios, participation rates, response rates, tourist occupancy, public shelter demand and capacity, and traffic control strategy. This will establish a range of clearance times within which the actual value for any particular storm should fall. Tables can be designed that will allow evacuation decision-makers to vary certain predetermined evacuation parameters to arrive at an estimated clearance time for any specific hurricane situation. Supporting data used in the development of the clearance times should be included in an appendix to the technical data report.

(k) Traffic Control Measures. The movement of evacuating vehicles during a hurricane evacuation requires extensive traffic control efforts to make maximum use of roadway capacity and to expedite safe escape from hurricane hazards. The transportation analysis should reveal critical roadway segments and intersections and recommend specific traffic control measures and/or roadway modifications to help alleviate the anticipated problems in these areas. The development of traffic control techniques for critical evacuation routes should always involve state and local police, emergency management, and fire department officials and, if appropriate, the U.S. Coast Guard for bridges.

(l) Transportation Modeling Support Document. A transportation appendix to the technical data report should be provided to document data assumptions and files.

EVACUATION DECISION-MAKING.

a. General.

Several approaches developed by the USACE, FEMA, and the private sector are available to state and local officials to aid in hurricane evacuation decision making.

These include the Decision Arc Method and the HURREVAC, GDS, HURRTRAK, and other computer programs. The Decision Arc Method, HURREVAC, and GDS are related techniques that determine the latest time at which an impending evacuation order or advisory should be given by integrating information extracted from the NHC Tropical Cyclone Forecast with data developed in the hurricane evacuation study. They also take into account strike probabilities produced by the NHC. Since several factors must be weighed in evacuation decision making, none of these approaches is designed to be a decision-making mechanism.

The Decision Arc Method was developed by the USACE to deal with inherent problems in relating hurricane evacuation to "eye landfall". It departs from the "time-to-landfall" approach by translating clearance times into distances on a hurricane tracking chart, and prelandfall hazards times into distances on a two-dimensional hurricane graphic. This combination visually depicts a threatening hurricane situation. HURREVAC, developed by FEMA, and some computer programs available commercially function in a fashion similar to the Decision Arcs but use a system based on local time rather than distances. Since these programs depend on an operating computer, they should always be backed up by the manual Decision Arc Method.

b. Decision Arc Method.

(1) General. When a hurricane approaches a coastline at an acute angle, as is the usual case along the Atlantic seaboard, a small error in the forecast track can rather drastically change the point of landfall, significantly increasing or decreasing the distance and time to landfall. The forward motion of hurricanes can also accelerate and decelerate, causing the time of landfall to be even more unpredictable. Rather than base hurricane evacuation decision making and mobilization on forecast time and point of landfall, methods are available to help compensate for forecast errors by relating evacuation operations to actual hurricane position and movement.

The Decision Arc Method employs two separate but related components which, when used together, present a graphic depiction of the hurricane situation as it relates to each jurisdiction. A specialized hurricane tracking chart, the Decision Arc Map, is paired with a two-dimensional hurricane graphic, the STORM, to describe the approaching hurricane and its relation to the area considering evacuation.

(2) Decision Arc Map and STORM. Decision Arcs are nothing more than clearance times converted to distance by accounting for the forward speed of the

hurricane. This method requires the development of special hurricane tracking charts with a series of concentric arcs usually centered on the southernmost boundary of each county. The largest of these concentric arcs should have a radius at least as large as the quotient of the longest clearance time, measured in hours, multiplied by the greatest expected hurricane forward speed, expressed in knots. The resulting radius would be measured in nautical miles.

The Special Tool for Observing Range and Motion (STORM) is used as a two-dimensional depiction of an approaching hurricane. It is a transparent disk with concentric circles spaced at equal nautical mile intervals, their center representing the hurricane eye. These circles form a scale used to note the radii of tropical storm winds reported by the NHC in the Tropical Cyclone Forecast.

(3) Method of Application. To translate a clearance time into nautical miles (Decision Arc distance) for use with the Decision Arc Map, simply multiply the clearance time by the forward speed of the hurricane in knots. This calculation yields the distance in nautical miles that the hurricane will move while the evacuation is underway. For convenience, a Decision Arc Table can be developed for each community to convert an array of clearance times and forward speeds to respective Decision Arcs. To use the Decision Arc method, officials plotting an approaching hurricane on the Decision Arc Map should make an evacuation decision prior to the time when the selected radius on the STORM crosses the appropriate Decision Arc (the Decision Point). As the Decision Point nears, factors such as hurricane category, NWS probabilities, forward speed/acceleration, and possible forecast errors must be considered. Once the selected STORM radius crosses the Decision Arc, there is no longer sufficient time to safely evacuate the vulnerable population without employing extraordinary measures to hasten their departure.

c. HURREVAC Computer Program.

HURREVAC includes many of the features of the Decision Arc Method. It uses the radii of tropical storm winds and hurricane forward speed reported in the NHC Tropical Cyclone Forecast to determine the prelandfall hazards time for an approaching hurricane. The program then assumes a worst-case scenario by adjusting the forecast track to aim the hurricane directly toward the jurisdiction in question. Therefore, as with the Decision Arc Method, evacuation timing is not related to a forecast point of landfall or time of landfall. By integrating the calculated prelandfall hazards time with clearance times from the technical data report already contained in the program, HURREVAC will calculate the local time when an evacuation decision must be made, the time when tropical storm winds could arrive in the community, and the time when the hurricane eye could make landfall. The probability values from the NHC Tropical Cyclone Forecast are incorporated into another feature of the program. Using those values, along with the hurricane category, forward speed, and track, the program will select from an array of evacuation scenarios the evacuation decision most often made, historically, under similar circumstances.

The HURREVAC program also includes graphic displays of the evacuation zone maps for the study area; past, present, and forecast hurricane locations; and the tropical storm wind field. A separate display of the inland wind field information mentioned previously [see Hazards Analysis, Wind Hazards] is available for the entire Gulf of Mexico coastline and the Atlantic coast as far north as North Carolina.

STUDY PRODUCTS

a. Technical Data Report.

The technical data report gives a detailed description of how the study was performed and the study results. It should contain written descriptions of the conduct and results of each study task and all maps, diagrams, and tables needed to support those descriptions. The inundation maps, sometimes called storm surge atlases, should be printed separately. Separate detailed appendices should be used as necessary to prevent the basic document from becoming too cumbersome.

The technical data report should be distributed to all Federal, state, and local officials involved in hurricane evacuation planning and decision making within the study area. At least one copy should be furnished to each agency assigned a role in hurricane preparedness.

b. Evacuation Plan Support.

The USACE should provide technical assistance to state and local emergency management officials in preparing or revising evacuation plans. Assistance should be in the form of interpreting information developed in the evacuation study and training in the use of that information. Training should include a tabletop exercise, preferably involving FEMA and the NWS, using the Decision Arc Method and any other available decision-making aids.

c. **Public Information Materials.**

The Study Manager should work with state and local emergency management officials to develop and disseminate publicity designed to educate potential evacuees. Public information materials can take many forms: brochures for distribution in the study area, tabloids printed by local newspapers, information printed into telephone books, taped audio and visual presentations, slide presentations, wall maps, and others. USACE participation in developing and disseminating public information materials should be limited to providing and interpreting technical data directly related to the study. In past studies, this has been accomplished principally with slide presentations illustrating important technical data. This can include such information as potential surge heights, prominent buildings with inundation levels depicted, inundation maps, evacuation zones, evacuation routes, shelter locations, etc.

EVACUATION EXERCISE

A regional hurricane evacuation exercise sufficient in scope to test all major elements of the hurricane evacuation plans should be conducted. The participants should include state, regional, and local agencies that have hurricane emergency preparedness responsibilities. The scope could range from only tabletop communications to full activation of field personnel and emergency operations centers. Regardless of the scale, the goal of the exercise should be to test the effectiveness of each plan in affording the public a safe, efficient, and effective evacuation from a hurricane threat.

The exercise should test the ability of emergency management officials to identify the appropriate evacuation scenario as it develops, including those of neighboring communities. Official's responses should be tested in the areas of evacuation decision making, communications, public warnings, manpower/equipment deployment, resource allocation, timing of evacuation order or advisory, shelter activation, emergency transportation, and traffic control. Communications and emergency power systems should be fully tested, long-term if possible. Monitors should be stationed at each emergency operations center and, if appropriate, in the field to evaluate response activity.

A post-exercise review should be conducted to evaluate the effectiveness of each plan. Officials who participated in the exercise should also contribute to the review. Monitors should be asked to critique the activity to which they were assigned. A critique report should be published at the state level that documents the exercise methodology, identifies problem areas, and recommends improvements. Areas where future preparedness training would be beneficial should also be identified.

STUDY MAINTENANCE, UPDATES, AND RESTUDIES

There are no rigid boundaries between hurricane evacuation study maintenance, updates and restudies. Rather, there is a gradual increase in scope and/or complexity as the effort moves from maintenance to update to complete restudy. The following paragraphs address typical features and activities which might be expected to fall within these categories.

a. Hurricane Evacuation Study Maintenance.

As part of a state or local jurisdiction's yearly maintenance of hurricane evacuation plans and procedures, they should routinely evaluate certain data treated or developed by the hurricane evacuation study. Information about changes in population, numbers of seasonal housing units and/or mobile homes; availability of more detailed topography; changes in shelter inventories; and changes to access/egress routes (new bridges, roads, ferries) is often most readily accessible to a local jurisdiction. This information is acted on in several possible ways: adjustments by the jurisdiction to its evacuation plan data and/or operations; sharing of information with neighboring jurisdictions which may be affected; and providing information for a technical or regional analysis. When the changes in the study area circumstances reach an appropriate level of magnitude or complexity, state officials should seek the services of the FEMA hurricane program for an update or restudy. Ongoing maintenance of the data base should result in much faster and more efficient updates and/or restudies.

Study maintenance may include various activities which assume the current study products are largely accurate and usable. USACE Study Managers are frequently involved in these activities. Examples may include training for state and local emergency management officials, technical assistance (requested by state or local officials) concerning growth management and resource sharing, or other issues. It is recommended that USACE study management districts include anticipated training and maintenance activities in their annual HES budget requests.

b. Hurricane Evacuation Study Update.

This effort is triggered by changes in characteristics of the study area or availability of advances in study procedures or products that have the potential to improve the capabilities of states or local jurisdictions. No significant changes in expected surge limits are anticipated from the base study. Minor changes to behavioral assumptions may be made but no new public surveys are performed. The transportation analysis is revised to reflect significant population increases, roadway improvements on key evacuation corridors, and public shelter changes. Additional evacuation scenarios may be incorporated based on new traffic control assumptions. Study updates will include evaluating alternatives that may lower long evacuation clearance times. New base mapping may be incorporated and digital/GIS technology introduced where previously unavailable. Decision making tools are revised with new clearance times and shelter list changes. Tables in the current technical data report are revised as necessary.

c. Hurricane Evacuation Study Restudy.

This effort is triggered by major changes in characteristics of the study area or availability of advances in study procedures or products. Examples would include: large increases in vulnerable population; a direct hit by a hurricane resulting in demographic changes or expected public response; changes to the SLOSH model that result in significant differences in expected surge limits. Some or all study components would need to be revisited. A major revision of the technical data report is accomplished and updated tools for decision making are provided.

d. Hurricane Evacuation Study Multi-Region Study.

This analysis meshes together evacuation data from several different hurricane evacuation studies. Impacts of one region's evacuees on another region are considered. Major public transportation providers are identified for hazards and vulnerability analysis and for evacuation clearance time considerations. Forums are provided for different states and regions to coordinate on responses and information flow that will need to take place for future storm events.

APPLICATION OF NEW TECHNOLOGY AND LESSONS LEARNED

As the national hurricane evacuation experience base increases, there will be continual advances in evacuation planning concepts and operations procedures. Changes in the "state of the art" of hurricane evacuation studies will reflect these advances. It can be expected that at certain times individual or multiple study areas will be able to benefit from additions or modifications to their study products as indicated by experience in other jurisdictions. Similarly, factors such as advances in surge modeling, evacuation decision software, mapping, shelter selection criteria, etc. can be expected to eventually reach a point where an update or a restudy is indicated.

CLEARANCE TIMES AND HURRICANE EVACUATION STUDY UPDATES/RESTUDIES PRIORITIES

In some jurisdictions, the size of the vulnerable population, lack of evacuation routes, or other factors have produced calculated clearance times of 24 hours or more. Clearance times of this length can require jurisdictions to make evacuation decisions when hurricane strike probabilities are rather low. For these areas, any changes in clearance times can be critical. All other factors being equal, study areas with longer clearance times will have higher priority to receive Federal funding for updates than those with more manageable times. In considering requests for funding of hurricane evacuation study updates or restudies, FEMA Headquarters and the HQUSACE will place significant emphasis on areas with clearance times of about 24 hours, or if there is reason to believe that the changes will lead to such clearance times.

LIST OF EXHIBITS

EXHIBIT 1 - Letter, dated January 3, 1994, from Mr. Billy R. Cameron, Director, North Carolina Department of Crime Control and Public Safety, Division of Emergency Management to Mr. Major P. May, Regional Director, Federal Emergency Management Agency, Region IV.

EXHIBIT 2 - Letter, dated 12 July 1985, from Wayne A. Hanson, Colonel, Wilmington District, U.S. Army Corps of Engineers, to Commander, South Atlantic Division, U. S. Army Corps of Engineers.

EXHIBIT 3 - Letter, dated 8 August 1985, from Dan M. Mauldin, Chief, Planning Division, South Atlantic Division, U.S. Army Corps of Engineers, to Commander, Wilmington District, U.S. Army Corps of Engineers, Attention: SAWPD.

EXHIBIT 4 - Memorandum of Agreement Between The State of North Carolina, Department of Crime Control and Public Safety, Division of Emergency Management and U.S. Army Corps of Engineers, Wilmington District, dated 9 May 95.

North Carolina Department of Crime Control and Public Safety
Division of Emergency Management

James B. Hunt, Jr., Governor

Thurman B. Hampton, Secretary

January 3, 1994

Mr. Major P. May, Regional Director
Federal Emergency Management Agency
Region IV
1371 Peachtree Street, N.E.
Atlanta, Georgia 30309

Dear Mr. May:

The Eastern North Carolina Hurricane Evacuation Study was initiated in 1984 and completed in 1987. As you know, the study was funded by the Federal Emergency Management Agency, the U.S. Army Corps of Engineers, and the North Carolina Division of Emergency Management, Department of Crime Control and Public Safety. When it was completed, it provided state and local government officials with a wide-range of hurricane evacuation information upon which sound evacuation decisions could be made.

Since 1984, the coastal counties in our State have experienced rapid change, with significant development and population increases occuring over the past ten years. The majority of this coastal development has been on the barrier islands, at or near the Atlantic coastline, and along the intracoastal waterway.

Last year, the National Hurricane Center completed the Myrtle Beach/Wilmington SLOSH Basin Model. The data obtained from this new model on fast-moving hurricanes reflects significantly higher storm surge values for our four Southeastern coastal counties. This data was not available during the original study in 1984.

During Hurricane Emily at the end of August 1993, the National Hurricane Center made available the SLOSH model data for what might be expected for storm surge heights from sound side flooding on Hatteras Island. The actual storm surge in the Buxton area on the sound side of the island was almost double what the model had indicated. This has resulted in a reevaluation, by the National Weather Service, of the Pamlico SLOSH Basin Model with a strong indication that the model will probably be redone in the near future.

After evaluating these various factors, I believe it is essential that FEMA and the Corps conduct a restudy of the original hurricane evacuation study. There are a sufficient number of reasons that highlight the importance of a restudy, and I am asking for your support on this major project.

Enclosed is a report prepared by the Wilmington District, U.S. Army Corps of Engineers, titled "Report of Recommendation for Hurricane Evacuation Restudy for Coastal North Carolina". We have been working on this restudy project during the past year with the Wilmington District, and I feel that it is important enough that I have made it my number one Division priority for 1994.

I have discussed this project, its importance, and the required funding that would be necessary for its completion, with the Secretary for the Department of Crime Control and Public Safety. We intend to ask the North Carolina General Assembly to provide $390,000, over a three year period, as the State's cash contribution for this restudy.

I certainly appreciate your continued support of our state program activities and will be glad to answer any questions you may have on this restudy request. Thanks again for your outstanding support and assistance.

Sincerely,

Billy R. Cameron

Billy R. Cameron
Director

BRC:wb
Enclosure

bcc: Al Bjorkquist

DEPARTMENT OF THE ARMY
WILMINGTON DISTRICT, CORPS OF ENGINEERS
P.O. BOX 1890
WILMINGTON, NORTH CAROLINA 28402-1890

IN REPLY REFER TO

SAWPD

12 July 1985

SUBJECT: Eastern North Carolina Hurricane Evacuation Study

Commander, South Atlantic Division

1. Reference is made to the following:

a. ER 1140-2-303

b. ER 1105-2-10

2. The Wilmington District has received a request from the North Carolina Department of Crime Control and Public Safety to accept a $50,000 cash contribution to help defray the cost of conducting the subject study (see attached letter). The cost of this study is estimated to be $460,000. To date, funds have been made available as follows: Corps of Engineers, $152,000; Federal Emergency Management Agency, $55,000; State of North Carolina, $50,000. The initial State contribution of $50,000 was made to FEMA and transferred to the Wilmington District through a modification to our interagency agreement with FEMA. Subsequently, FEMA has notified the State that additional contributions should be made directly to the Wilmington District.

3. Reference 1.a. above defines the type of services which may be provided to the state and local governments by Civil Works activities of the Corps of Engineers, under authority of Title III of the Intergovernmental Cooperation Act of 1968 (P.L. 90-577, 82 Stat. 1102), as implemented by the Bureau of the Budget Circular A-97, 29 August 1969. Paragraph 6.a.(2) provides for the preparation of statistical or other studies or compilations, technical tests and evaluations, technical information, surveys, reports, and documents, and assistance in the conduct of such activities and in the preparation of such materials, provided they are of a type similar to those which the Federal agency is authorized by law to conduct or prepare. ER 1140-2-303 also provides for payment or reimbursement, by the unit of government making the request, of salaries and other direct and indirect costs. Paragraph 5-5 of ER 1105-2-10 (reference 1.b.) discusses the role of the Flood Plain Management Services Program in support of flood emergency evacuation planning. Thus, it appears that existing authorities and policies allow for the acceptance and expenditure of funds contributed by state agencies for Corps of Engineers flood evacuation planning studies.

EXHIBIT 2

SAWPD 12 July 1985
SUBJECT: Eastern North Crolina Hurricane Evacuation Study

4. I request your approval and the Chief of Engineers authorization for the Wilmington District to accept the cash contribution by the North Carolina Department of Crime Control and Public Safety in order that the Eastern North Carolina Hurricane Evacuation Study can proceed in a timely and expeditious manner.

Wayne A. Hanson

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as

WAYNE A. HANSON
Colonel, Corps of Engineers
Commanding

DEPARTMENT OF THE ARMY

SOUTH ATLANTIC DIVISION, CORPS OF ENGINEERS
510 TITLE BUILDING, 30 PRYOR STREET, S.W.
ATLANTA, GEORGIA 30335-6801

REPLY TO ATTENTION OF: SADPD-F

8 August 1985

SUBJECT: Eastern North Carolina Hurricane Evacuation Study

Commander, Wilmington District
ATTN: SAWPD

1. Reference:
   a. SAWPD letter dated 12 Jul 85, subject as above.

   b. ER 1140-1-211

   c. ER 1140-2-303

2. Reference 1b and 1c provide guidance on performing reimbursable work for others. The services described in reference 1a meet the criteria in paragraph 5b (1) of ER 1140-1-211 for work that can be approved by Division Commanders. If all applicable requirements of the Engineer Regulations referenced above are met, you are authorized to accept and perform the reimbursable work for the State of North Carolina described in reference 1a.

3. The work to be performed for the State should be defined in a Memorandum of Agreement (MOA) between the State of North Carolina and Wilmington District. Samples of MOAs prepared by other districts are enclosed for your information. Please furnish a copy of the MOA to SADPD-F after it has been executed.

FOR THE COMMANDER:

Dan M. Mauldin

Encls

DAN M. MAULDIN
Chief, Planning Division

EXHIBIT 3

MEMORANDUM OF AGREEMENT
BETWEEN
THE STATE OF NORTH CAROLINA,
DEPARTMENT OF CRIME CONTROL AND PUBLIC SAFETY,
DIVISION OF EMERGENCY MANAGEMENT
AND
U.S. ARMY CORPS OF ENGINEERS, WILMINGTON DISTRICT

I. SUBJECT

Study of the North Carolina coast consisting of conducting a new hazards analysis of the Pamlico Sound Basin area as part of the Hurricane Evacuation Restudy.

II. PURPOSE

The purpose of this Memorandum of Agreement (MOA) is to define the responsibilities, timing and the cost for the preparation of a new hazards analysis using the Sea, Lake and Overland Surges (SLOSH) Model to develop data for fourteen counties in the Pamlico Sound Basin area as part of the Hurricane Evacuation Restudy.

III. PARTIES

The parties to this Memorandum of Agreement (MOA) are: North Carolina Department of Crime Control & Public Safety, Division of Emergency Management (EM) and the U.S. Army Corps of Engineers, Wilmington District (Corps).

IV. BACKGROUND

North Carolina is the most vulnerable of the Atlantic coast states to hurricanes that originate in the Atlantic Ocean. Forty-seven hurricanes have directly affected eastern North Carolina since officials began keeping weather records in 1886. Due to the state's vulnerability to hurricanes, North Carolina was selected as one of the first coastal states to conduct a hurricane evacuation study. The Eastern North Carolina Hurricane Evacuation Study was conducted between 1984 through 1987. Study partners included the State of North Carolina, the Federal Emergency Management Agency (FEMA), the National Hurricane Center, and the U.S. Army Corps of Engineers (Corps). The Corps served as the Study Manager. The study area consisted of the following eighteen counties: Beaufort, Bertie, Brunswick, Camden, Carteret, Chowan, Craven, Currituck, Dare, Hyde, New Hanover, Onslow, Pamlico, Pasquotank, Pender, Perquimans, Tyrrell and Washington. Martin and Jones Counties were included in the transportation analysis segment of the study. The storm surge inundation data for the four southeastern counties was obtained using an older computer model known as Special Program to List the Amplitude of Surges

EXHIBIT 4

from Hurricanes (SPLASH). This model was limited since storm surge heights were only calculated for open coastlines.

In 1992, the National Hurricane Center began work on the Sea, Lake and Overland Surges (SLOSH) model for the Wilmington/Myrtle Beach coastal basin area. The Pamlico Basin SLOSH model used in the 1987 study provided effective storm surge inundation coverage from the Virginia border to the midpoint of Onslow County near the New River Inlet. In 1989, Hurricane Hugo smashed into the South Carolina coast moving at a forward speed in excess of 25 mph. This event highlighted the need to update storm surge information compiled for North Carolina's hurricane evacuation planning.
In 1992, the National Hurricane Center completed storm surge modeling for four southeastern counties in North Carolina. The model showed startling results. For instance, surge values for large, fast-moving hurricanes were found to be significantly higher (in some cases as much as 10 feet higher) than surge values that were reported for similar category storms in the initial 1987 North Carolina Hurricane Evacuation Study. Thus, it was determined that the SLOSH results for the entire coastal North Carolina study area needed to be updated. Such information should be incorporated in all facets of a restudy and disseminated in an effective and useful manner.

In December, 1993, the Corps prepared a Report of Recommendation for Coastal North Carolina Hurricane Evacuation Restudy (Report). The purpose of the Report was to determine the changes along the North Carolina coast that occurred since the data was compiled in the North Carolina Hurricane Evacuation Study published in November, 1987. In the period between the beginning of the original study, the coastal area of North Carolina incurred rapid change. The area experienced significant development and an estimated 20% increase in the residential population and a significant increase in tourism. The Report recommended a restudy of the entire North Carolina coast. It was believed that another study was necessary for the following reasons: 1) advances in computer modeling showed that storm surge inundation was from five to ten feet higher than that shown in the original study; 2) greater numbers of citizens were at risk from hurricanes; 3) longer clearance times were necessary to safely evacuate citizens; 4) better analysis of hurricane shelters and the effect of 100+ mph winds on the shelters was needed; 5) it became necessary to route evacuation traffic through certain inland counties; and 6) an evaluation of the impact of evacuations to Virginia and South Carolina. Therefore, the restudy should consist of the preparation of digital storm surge maps. In addition, vulnerability and behavioral analysis should be conducted. The Report also recommended updating the 1987 shelter and transportation analysis.

The U.S. Army Corps of Engineers estimated that the cost of the additional study would be one million, seven hundred thousand dollars ($1,700,000.00) over a four year period. The estimated completion date for the restudy is 1998. On January 3, 1994, the N.C. Division of Emergency Management endorsed the above-referenced Report. EM indicated that it would seek funding for the restudy from the N.C. General Assembly as the state contribution toward the restudy. The Legislative Research Commission Committee on Emergency Management Issues recommended funding in the amount of one hundred and five thousand dollars ($105,000.00) per year through State Fiscal Year 1997-1998. The N.C. Legislature appropriated this amount for State fiscal year 1994-95 as the state share toward the re-study. FEMA and the Corps allocated funding for federal fiscal year 1995 for the restudy. The budget for the initial year of the study is as follows: FEMA, $150,000.00; Corps, $30,000.00; and the State of North Carolina, $105,000.00. In March, 1995, the U.S. Army Corps of Engineers, Wilmington District prepared a detailed Study Management Plan that defines responsibilities, timing and the cost for each study product. The restudy was approved by FEMA on March 6,1995. (See attached letter from Mr. Kenneth D. Hutchinson, Region IV Director to Mr. Billy Ray Cameron, N.C. Division of Emergency Management Director dated March 6, 1995). The major tasks to be undertaken and/or completed with this allocation is the update of the Pamlico Basin SLOSH Model, the completion of the ongoing mapping effort, and the initial Hurricane Evacuation Study data collection and review.

Three agencies contributed to the preparation and development of digitized storm surge inundation maps/atlases for the four southeastern counties. They are the U.S. Army Corps of Engineers (Corps), the Federal Emergency Management Agency (FEMA) and the N.C. Division of Emergency Management (EM). This effort consists of three phases. Phase 1A involved the preparation of work inundation maps/atlases. The work for Phase 1A was governed by the Memorandum of Agreement between the U.S. Army Corps of Engineers, Wilmington District and the Center for Geographic Information and Analysis (CGIA) dated September 23,1992. This MOA was modified on September 29,1993. Funding for Phase 1A was provided by FEMA and the Corps.

Phase 1B involved the preparation of a few sets of county surge atlases to be used for review prior to final printing. Phase 2 involves the printing of multiple copies of colored maps for county, state and individual use. Phase 2 will commence upon completion of Phase 1B. The work for Phase 1B is governed by the MOA between EM and CGIA which was executed on February 15,1995. Funding for Phase 1B was provided by the State of North Carolina.

V. AUTHORITY

The parties enter into this MOA under the authority of the Flood Control Act, 33 U.S.C. 701 et. seq.; the Intergovernmental Cooperation Act, 31 U.S.C. 6501 et. seq.; the Economy Act, 10 U.S.C. 3036(d); the type of services which may be provided to State and local governments by the U.S. Army Corps of Engineers is defined in ER-1140-2-303; and the N.C. Emergency Management Act, Chapter 166A of the North Carolina General Statutes.

VI. DUTIES AND RESPONSIBILITIES OF THE U.S. ARMY CORPS OF ENGINEERS, WILMINGTON DISTRICT

Upon receipt of funds from the State of North Carolina and receipt of funds from the Federal Emergency Management Agency (FEMA) as described in Section VII, "Funding and Compensation" below, the U.S. Army Corps of Engineers, Wilmington District agrees to manage work for the following:

Hazards Analysis. The Hazards Analysis determines the timing, severity, and sequence of wind and hurricane storm surge hazards that can be expected from hurricanes of various categories, tracks, and forward speeds striking the study area. The Sea, Lake, and Overland Surges (SLOSH) model will be used to develop the data for fourteen counties including Beaufort, Bertie, Camden, Carteret, Chowan, Craven, Currituck, Dare, Hyde, Pamlico, Pasquotank, Perquimans, Tyrrell and Washington. The Hazards Analysis will be performed by the National Hurricane Center.

The purpose of the Hazards Analysis is to quantify the still-water surge heights, waves, and wind speeds for various intensities and tracks of hurricanes considered to have a reasonable meteorological probability of occurrence within a particular coastal basin. Potential freshwater flooding from rainfall accompanying hurricanes is also addressed; however, due to the wide variation in amounts and times of occurrence from one storm event to another, rainfall can only be addressed in general terms.

The primary objective of the Hazards Analysis is to determine the probable worst-case effects from various intensity hurricanes that could strike the area. For the purposes of this study, the term worst-case is used to describe the peak surges, wind speeds, wave effects, and potential rainfall that can be expected at all locations within the study area regardless of the point of hurricane eye landfall.

VII. FUNDING AND COMPENSATION

The estimated cost of this project will be one hundred and forty thousand dollars ($140,000.00) for State fiscal year 1994-95. The Federal Emergency Management Agency allocated thirty-five thousand dollars ($35,000.00) to the SLOSH modelling effort. The Department of Crime Control & Public Safety, Division of Emergency Management will provide a lump-sum payment in the amount of one hundred and five thousand dollars ($105,000.00) to the U.S. Army Corps of Engineers, Wilmington District for services rendered pursuant to this Agreement to be paid within thirty (30) days following execution of this agreement. Payment will be made payable to: F&A Officer, USAED Wilmington. Payment will be mailed to the following address: USAED, Wilmington, ATTN: CESAWRM-F, P.O. Box 1890, Wilmington, N.C. 28402-1890.

VIII. MODIFICATION OF THE AGREEMENT

This Agreement and any exhibits and amendments annexed hereto and any documents incorporated specifically by reference represent the entire Agreement between the parties and superseded all prior oral and written statements or agreements. Modification of this Agreement must be in writing, approved and duly executed by the Corps and the Department of Crime Control and Public Safety, Division of Emergency Management.

IX. STATE PROPERTY

To the extent permitted by the laws governing each party, all confidential information of either party disclosed to the other party in connection with the services provided hereunder will be treated by the receiving party as confidential and restricted in its use to only those uses contemplated by the terms of this Agreement. Any information which is to be treated as confidential must be clearly marked as confidential prior to transmittal to the other party.

Upon completion of the Hazards Analysis, the Corps shall provide a copy of the Pamlico Basin SLOSH model computer data files to the Division of Emergency Management.

X. TERMINATION

This Memorandum of Agreement shall remain in effect until satisfactory completion of the services rendered pursuant to this Agreement provided that either party may terminate or suspend this agreement, without penalty, upon thirty (30) days written notice to the other party. If the agreement is terminated, the Corps shall return to the Department of Crime Control and Public Safety, Division of Emergency Management pro rata share of funds paid for services rendered pursuant to this agreement. In the event of termination, a copy of all finished or unfinished computer data files shall become the property of the Division of Emergency Management.

XI. COMMUNICATIONS

To provide consistent and effective communication between Corps and EM, each party shall appoint a Principal Representative to serve as its central point of contact responsible for coordinating and implementing this MOA. The Division of Emergency Management contacts shall be Mr. Billy Ray Cameron, Director, Mr. James Self, Assistant Director for Mitigation and Recovery and Mr. Will Brothers, Lead Natural Hazards Planner. The Corps contact shall be Mr. Albert Bjorkquist, Study Manager.

XII. EXECUTION

This MOA will become effective upon execution of both parties to the MOA. The date of execution shall be the date of the last signature.

Executed this ____ day of ______, 1995.

For the U.S. Army Corps of Engineers,
Wilmington District

BY: ______________________

U.S. Army Corps of Engineers,
Wilmington District
District Engineer
DATE: 9 May 95

For the Department of Crime
Control & Public Safety,
Division of Emergency Management

BY: Billy R Cameron

Division of Emergency Management,
Director

DATE: 5/4/95

BY: ______________________
William A. Dudley
Assistant Secretary
Department of Crime Control &
Public Safety
DATE: 5/5/95

BY: Jack W. Reavis
Jack Reavis, Controller
DATE: 5/5/95

APPROVED AS TO FORM SUBJECT TO EXECUTION BY WILLIAM A. DUDLEY, ASSISTANT SECRETARY OF CRIME CONTROL AND PUBLIC SAFETY.

MICHAEL F. EASLEY
ATTORNEY GENERAL OF NORTH CAROLINA

BY: Cheryl A. Perry
ASSOCIATE ATTORNEY GENERAL

DATE: 5-5-95

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